Supporting Information for

Pd(II)/Lewis Acid catalyzed regioselective indole olefination with dioxygen

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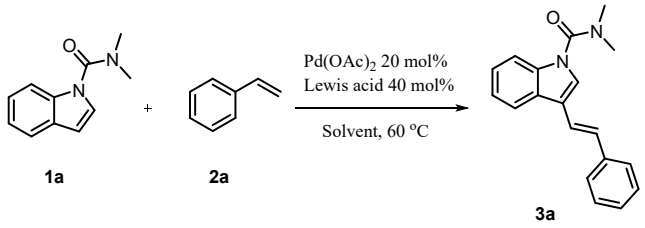
Content

1. Optimizations of the reaction conditions

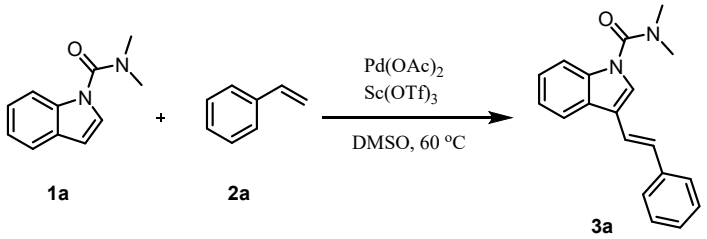
Table S1. Optimization of the reaction conditions for the indole olefination reaction [a]



Entry	Catalyst	Lewis acid	Solvent	Yield (%) [b]
1	$Pd(OAc)_2$	-	DMSO	16
2	$Pd(OAc)_2$	NaOTf	DMSO	10
3	$Pd(OAc)_2$	$Ca(OTf)_2$	DMSO	28
4	$Pd(OAc)_2$	$Zn(OTf)_2$	DMSO	35
5	$Pd(OAc)_2$	$Cu(OTf)_2$	DMSO	40
6	$Pd(OAc)_2$	$Cu(OAc)_2$	DMSO	35
7	$Pd(OAc)_2$	$Al(OTf)_3$	DMSO	50
8	$Pd(OAc)_2$	$Yb(OTf)_3$	DMSO	63
9	$Pd(OAc)_2$	$Y(OTf)_3$	DMSO	65
10	$Pd(OAc)_2$	$Sc(OTf)_3$	DMSO	75
11	$Pd(OAc)_2$	$Sc(OAc)_3$	DMSO	45
12	$Pd(OAc)_2$	ScF_3	DMSO	64
13	$Pd(OAc)_2$	$Sc(OTf)_3$	DMF	31
14	$Pd(OAc)_2$	$Sc(OTf)_3$	MeCN	n.d.
15	$Pd(OAc)_2$	$Sc(OTf)_3$	CH_3COOH	n.d.
16	$Pd(OAc)_2$	$Sc(OTf)_3$	Dioxane	n.d.
17	-	$Sc(OTf)_3$	DMSO	n.d.

[a] Reaction conditions: solvent (1.0 mL), **1a** (0.2 mmol), **2a** (0.4 mmol), $Pd(OAc)_2$ (20 mol%), Lewis acid (40 mol%), O_2 balloon, 60 ℃, 24 h. [b] Isolated yield.

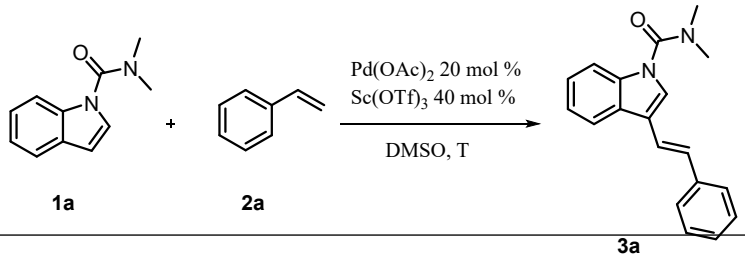
Table S2. Ratio and amount of the catalyst loadings for the indole olefination reaction [a]



Entry	$Pd(OAc)_2$:$Sc(OTf)_3$ (mol%)	Yield (%)[b]
1	10:20	54
2	15:30	60
3	20:40	75
4	20:20	63

[a]Reaction conditions: DMSO (1.0 mL), **1a** (0.2 mmol), **2a** (0.4 mmol), $Pd(OAc)_2$ (10-20 mol%), $Sc(OTf)_3$ (20-40 mol%), O_2 balloon, 60 ℃, 24 h. [b]Isolated yield.

Table S3. The influence of reaction temperature for the indole olefination reaction

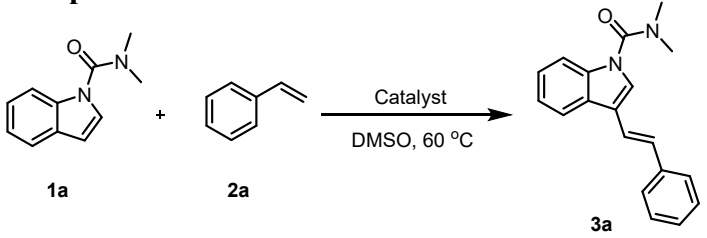


1a 2a 3a

Entry	Catalyst	Solvent	T (^{o}C)	Time (h)	Yield (%)
1	Pd(II)/Sc(III)	DMSO	50	24	35
2			60		75
3			70		60
4			80		54

[a] Reaction conditions: **1a** (0.2 mmol), **2a** (0.4 mmol), $Pd(OAc)_2$ (20 mol %), $Sc(OTf)_3$ (40 mol %), O_2 balloon. [b] Isolated yield.

Table S4. Control experiments for the indole olefination reaction [a]

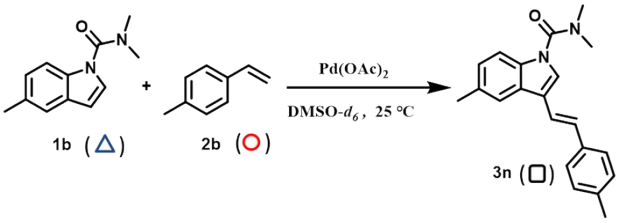


1a 2a 3a

Entry	Catalyst	Yield (%)[b]
1	$Pd(OAc)_2$	16
2	$Sc(OTf)_3$	n.d.
3	$Pd(OAc)_2$+$Sc(OTf)_3$	75
4	$Pd(OAc)_2$+HOTf (120 mol%)	11
5	$Pd(OTf)_2$	n.d.

[a]Reaction conditions: DMSO (1.0 mL), **1a** (0.2 mmol), **2a** (0.4 mmol), $Pd(OAc)_2$ (10-20 mol%), $Sc(OTf)_3$ (20-40 mol%), O_2 balloon, 60 °C, 24 h. [b]Isolated yield.

2. ^{1}H NMR kinetic studies of the reaction between *N*,*N*,5-trimethyl-1H-indole-1-carboxamide and 4-methylstyrene in the presence of one equivalent $Pd(OAc)_2$



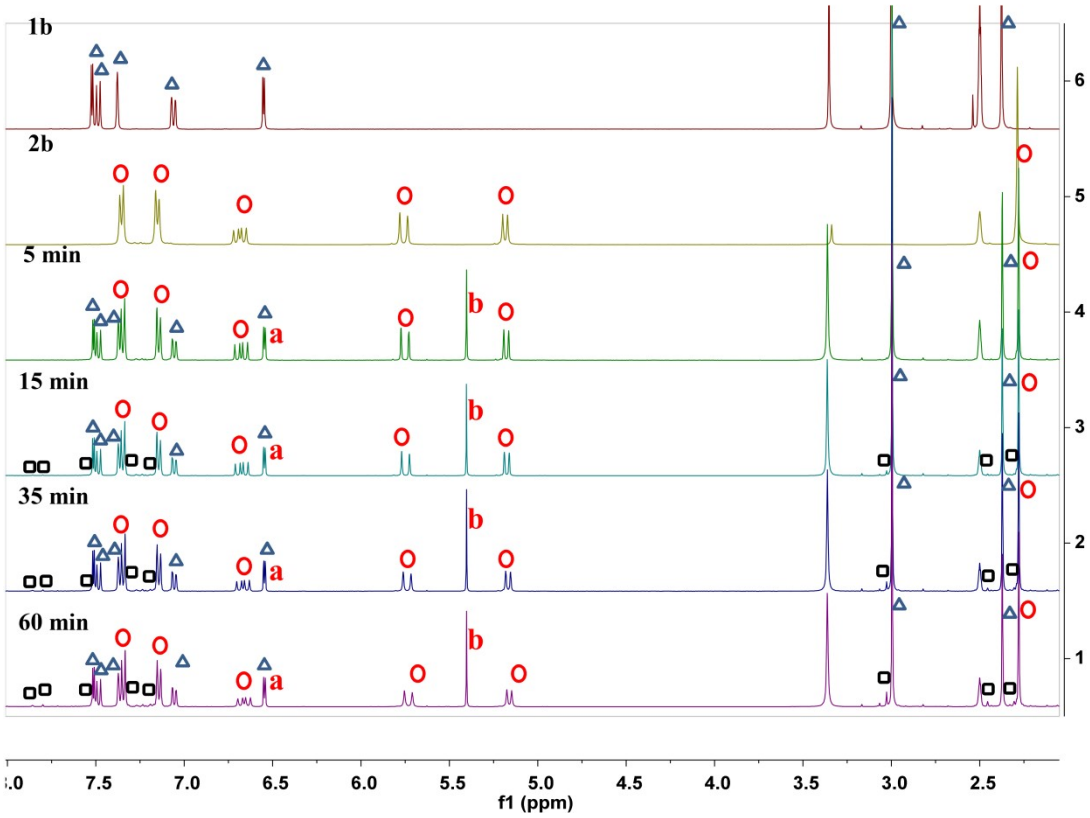
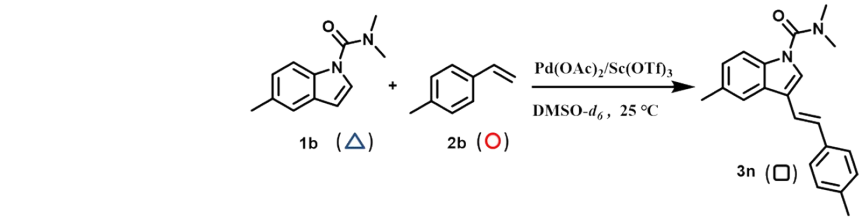


Fig. S1 ^{1}H NMR kinetics of **1b** (0.05 mmol) with **2b** (0.05 mmol) in DMSO-d_6 (0.6 mL) in the presence of one equivalent $Pd(OAc)_2$ at room temperature with CH_2Br_2 (0.025mmol) as the internal stanard.

3. ^{1}H NMR kinetic studies of the reaction between *N*,*N*,5-trimethyl-*1H*-indole-1-carboxamide and 4-methylstyrene in the presence of one equivalent $Pd(OAc)_2/Sc(OTf)_3$



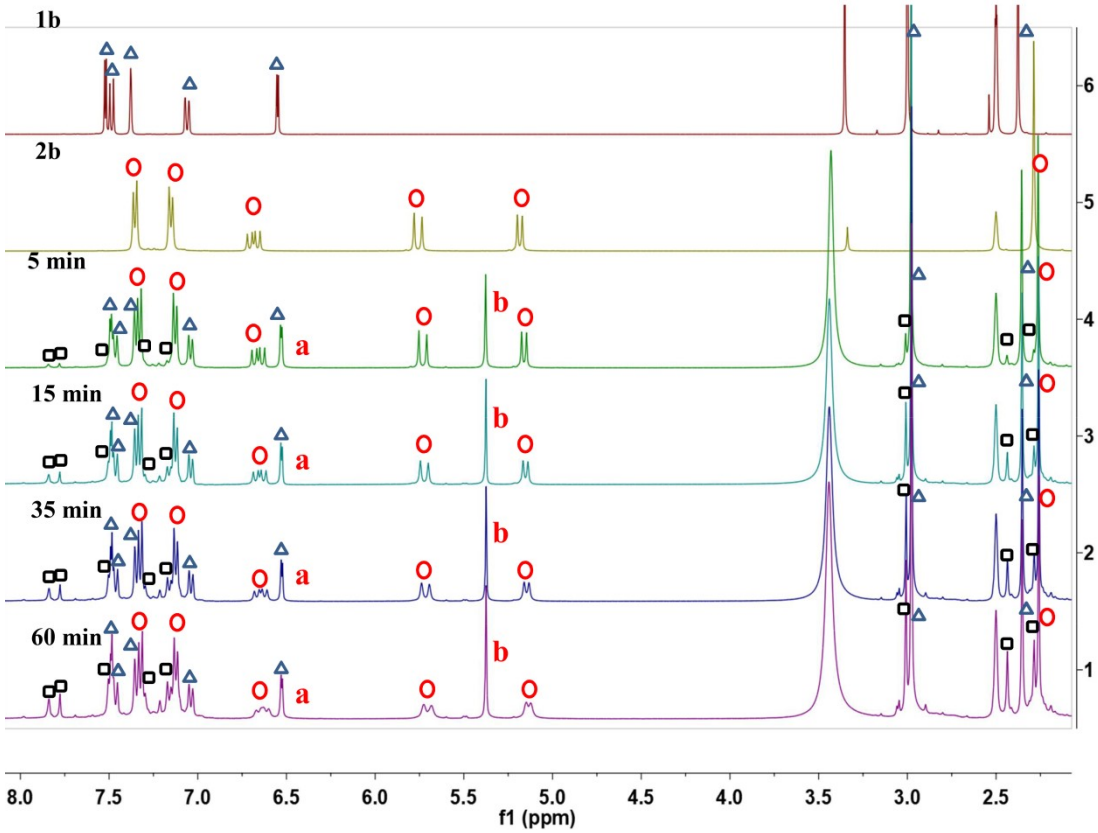


Fig. S2 ^{1}H NMR kinetics of **1b** (0.05mmol) with **2b** (0.05 mmol) in DMSO-d_6 (0.6 mL) in the presence of one equivalent $Pd(OAc)_2/Sc(OTf)_3$ at room temperature with CH_2Br_2 (0.025mmol) as the internal stanard.

4. The second-order kinetics of the olefination reaction between *N*,*N*,5-trimethyl-*1H*-indole-1-carboxamide and 4-methylstyrene monitored by ^{1}H NMR spectroscopy

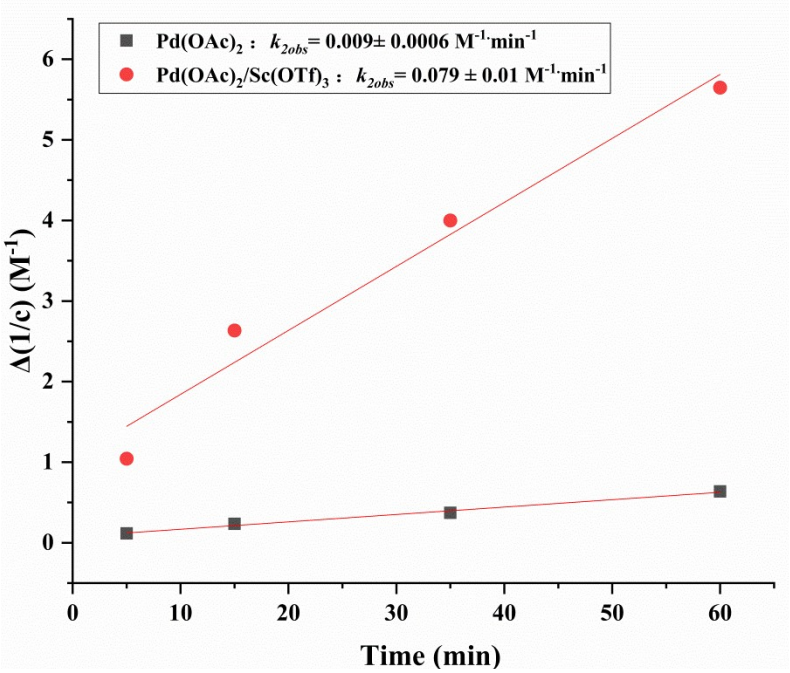
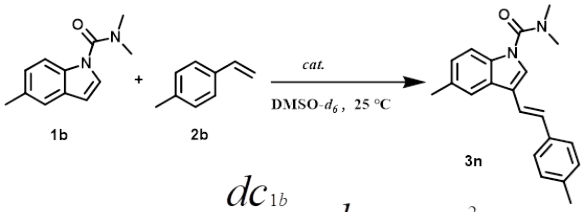


Fig. S3 The second order kinetics of the olefination reaction between **1b** (*N*,*N*,5-trimethyl-*1H*-indole-1-carboxamide) and substrate **2b** (4-methylstyrene),Δ(1/c) = 1/(0.083-c) – 1/0.083.

The kinetic calculations were carried out following the equations as below, where **a** is the initial concentration of **1b**, **y** is the conversion rate of **1b**, **t** is the reaction time, **1b** and **2b** have the identically initial concentrations:



$$r = -\frac{dc_{1b}}{dt} = k_{2obs} \cdot c_{1b}^{2}$$

$$\Rightarrow \frac{1}{c_{1b(t)}} - \frac{1}{c_{1b(t_0)}} = k_{2obs} \cdot t$$

$$\Rightarrow \frac{1}{a(1-y)} - \frac{1}{a} = k_{2obs} \cdot t$$

5. TLC kinetic observation of the reaction between *N,N*,5-trimethyl-*1H*-indole-1-carboxamide and methyl acrylate catalyzed by $Pd(OAc)_2$ (point 1) and $Pd(OAc)_2/Sc(OTf)_3$ (point 2) with dioxygen balloon

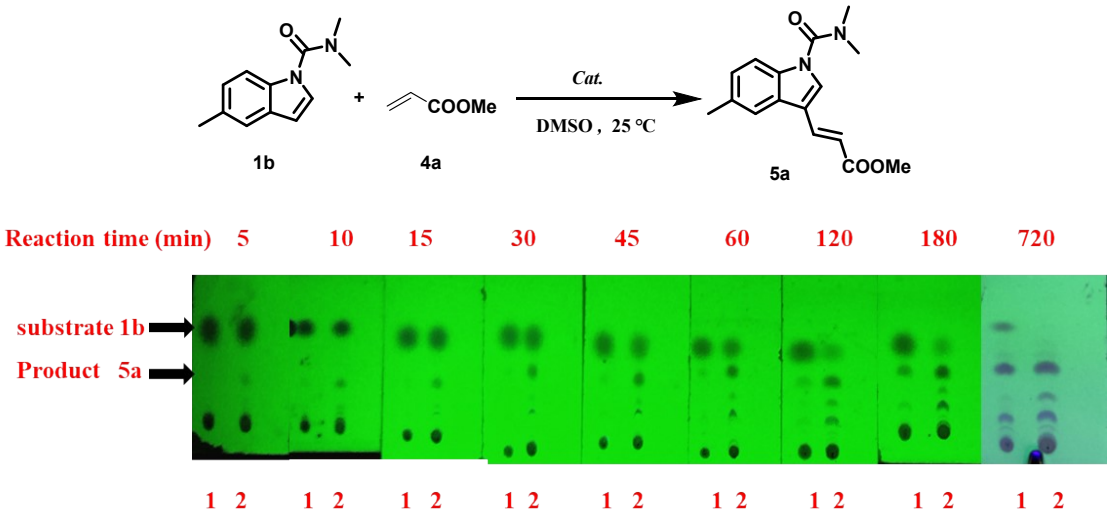


Fig. S4 Reaction conditions: *N,N*,5-trimethyl-*1H*-indole-1-carboxamide **1b** (0.05 mmol), methyl acrylate **4a** (0.05 mmol), $Pd(OAc)_2$ (0.05 mmol), $Sc(OTf)_3$ (0.05 mol), DMSO-d_6 (0.6mL), O_2 balloon, 25 °C.

6. ^{1}H NMR kinetics of the reaction between *N,N,5*-trimethyl-*1H*-indole-1-carboxamide and methyl acrylate in the presence of one equivalent $Pd(OAc)_2$

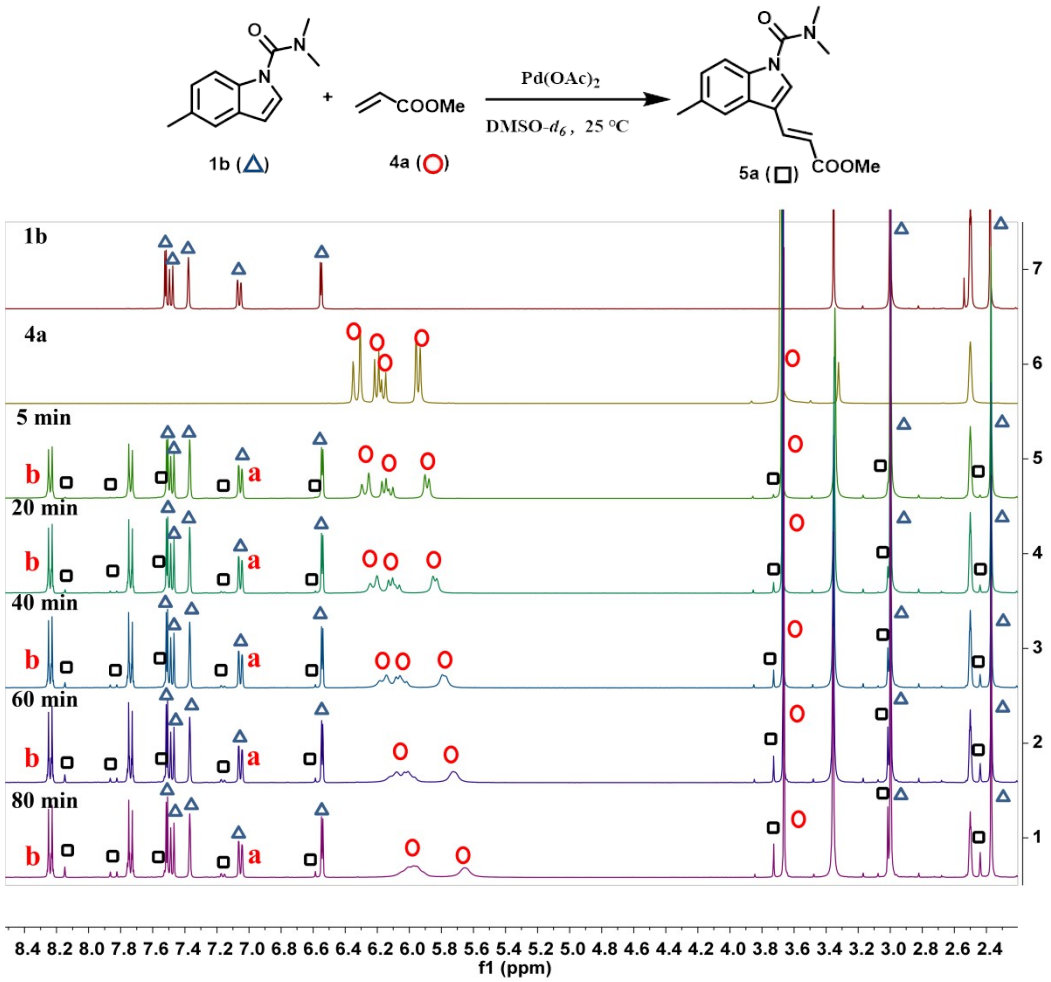
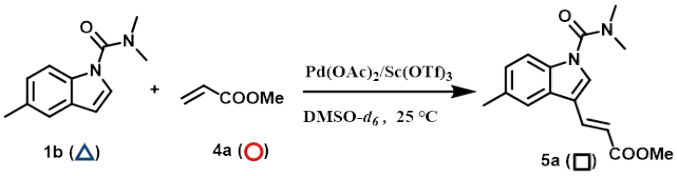


Fig. S5 ^{1}H NMR kinetics of **1b** (0.05mmol) with **4a** (0.05 mmol) in DMSO-d_6 (0.6 mL) in the presence of one equivalent $Pd(OAc)_2$ at room temperature with 4-chloronitrobenzene (0.025mmol) as the internal standard.

7. *¹H* NMR kinetics of the reaction between *N,N,5*-trimethyl-*1H*-indole-1-carboxamide and Methyl acrylate in the presence of one equivalent $Pd(OAc)_2/Sc(OTf)_3$



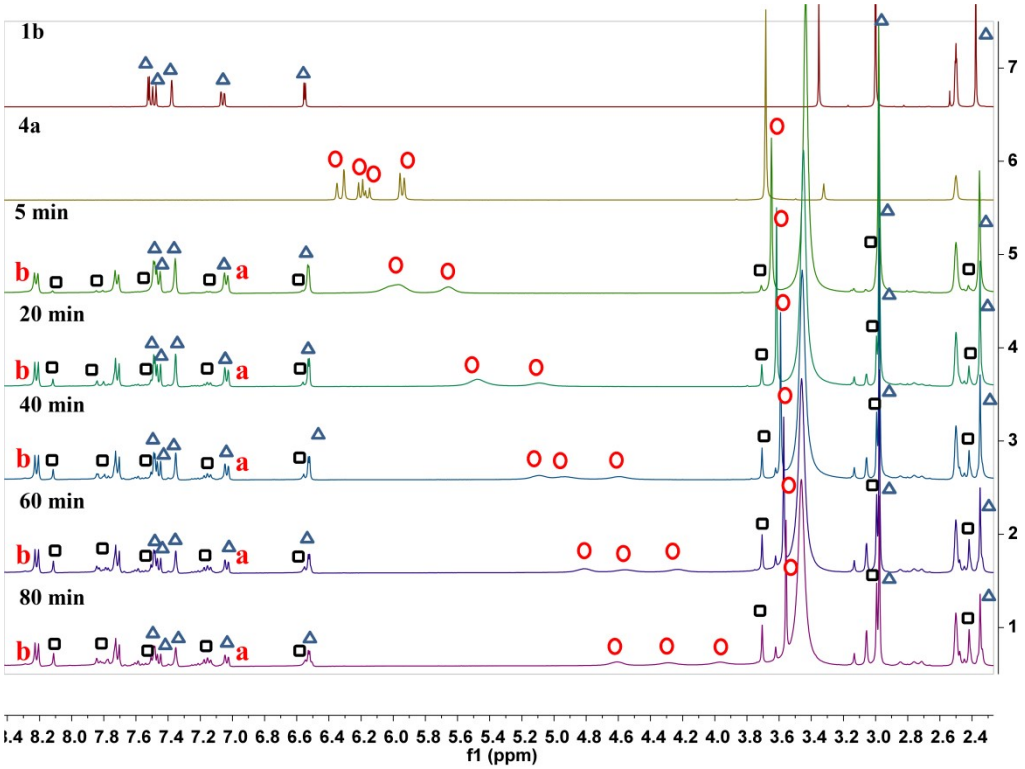


Fig. S6 ^{1}H NMR kinetics of **1b** (0.05mmol) with **4a** (0.05 mmol) in DMSO-d_6 (0.6 mL) in the presence of one equivalent $Pd(OAc)_2/Sc(OTf)_3$ at room temperature with 4-chloronitrobenzene（0.025mmol）as the internal standard.

8. The second-order kinetics of the olefination reaction between of *N*,*N*,5-trimethyl-*1H*-indole-1-carboxamide and methyl acrylate

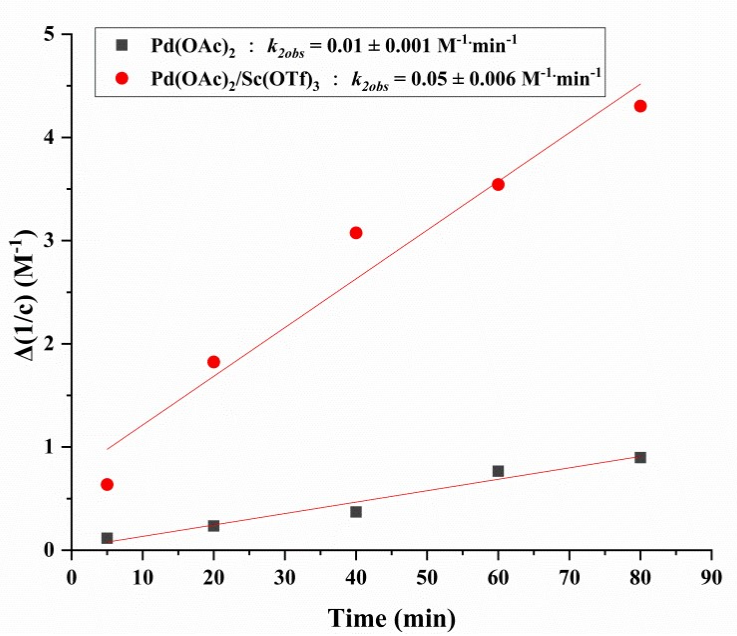
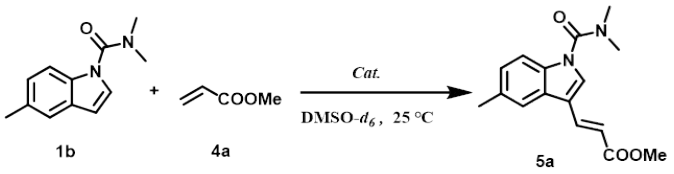


Fig. S7 The second order kinetics of the olefination reaction between **1b** and **4a** monitored by ^{1}H NMR spectroscopy, Δ(1/c) = 1/(0.083-c) – 1/0.083.

The kinetic calculations were carried out following the equations as below, where **a** is the initial concentration of **1b**, **y** is the conversion rate of **1b**, **t** is the reaction time, **1b** and **4a** have the identically initial concentrations:



$$r = -\frac{dc_{1b}}{dt} = k_{2obs} \cdot c_{1b}^{2}$$

$$\Rightarrow \frac{1}{c_{1b(t)}} - \frac{1}{c_{1b(t_0)}} = k_{2obs} \cdot t$$

$$\Rightarrow \frac{1}{a(1-y)} - \frac{1}{a} = k_{2obs} \cdot t$$

9. UV-vis spectra of the catalyst in DMSO

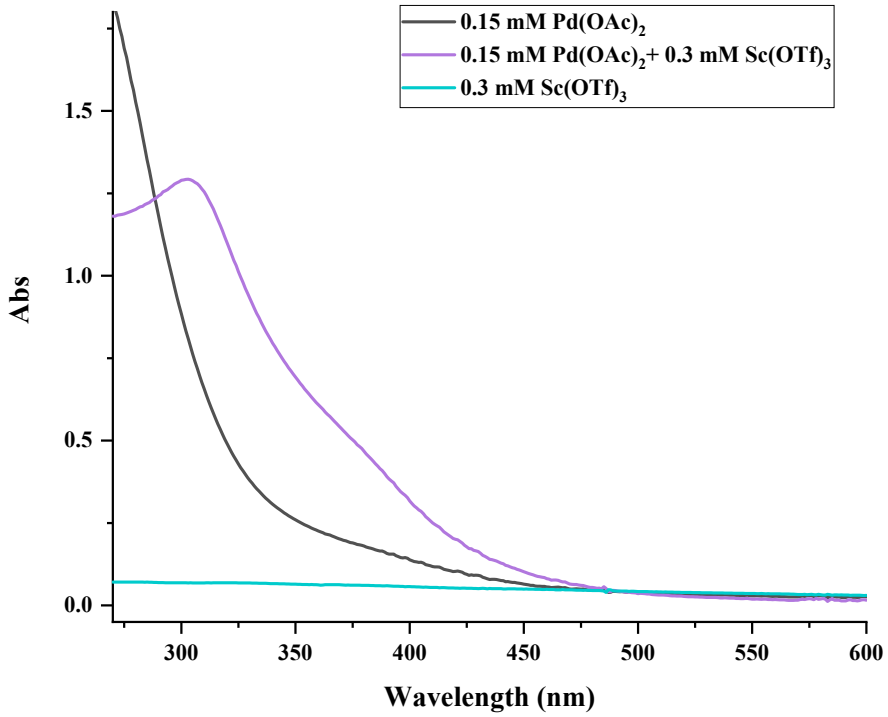


Fig. S8 UV−vis spectra of $Pd(OAc)_2$ and $Sc(OTf)_3$ in DMSO.

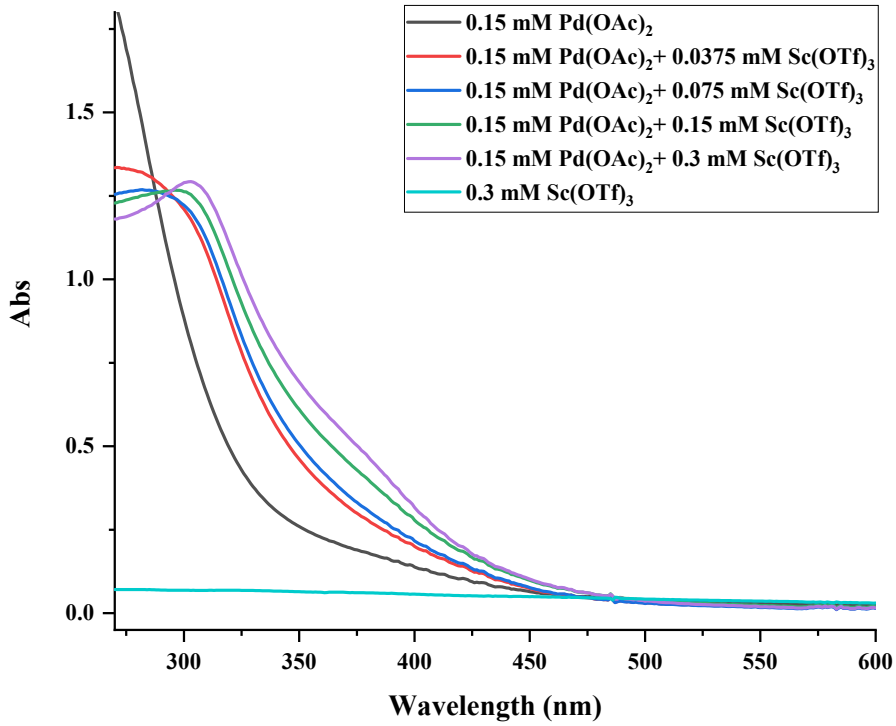
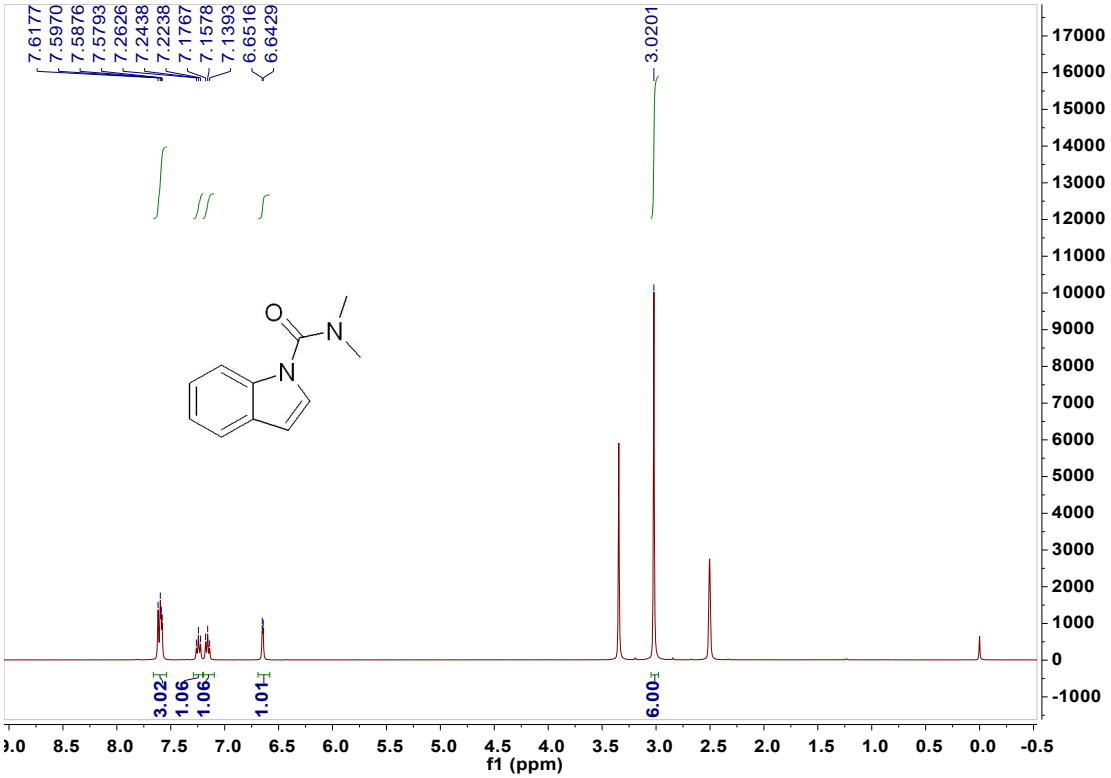


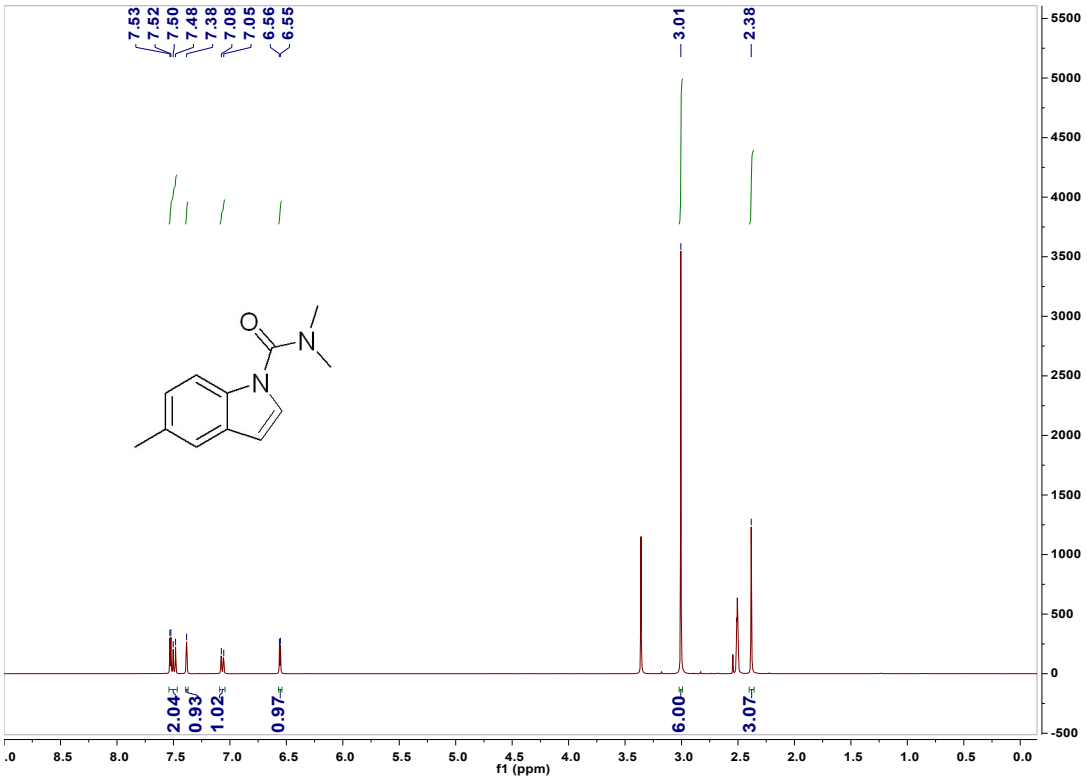
Fig. S9 UV-vis spectra of the Pd(II)/Sc(III) catalyst in DMSO. Conditions: 0.15 mM Pd(II), 0-0.3 mM Sc(III), room temperature.

10. ^{1}H NMR and ^{13}C NMR spectra of all compounds

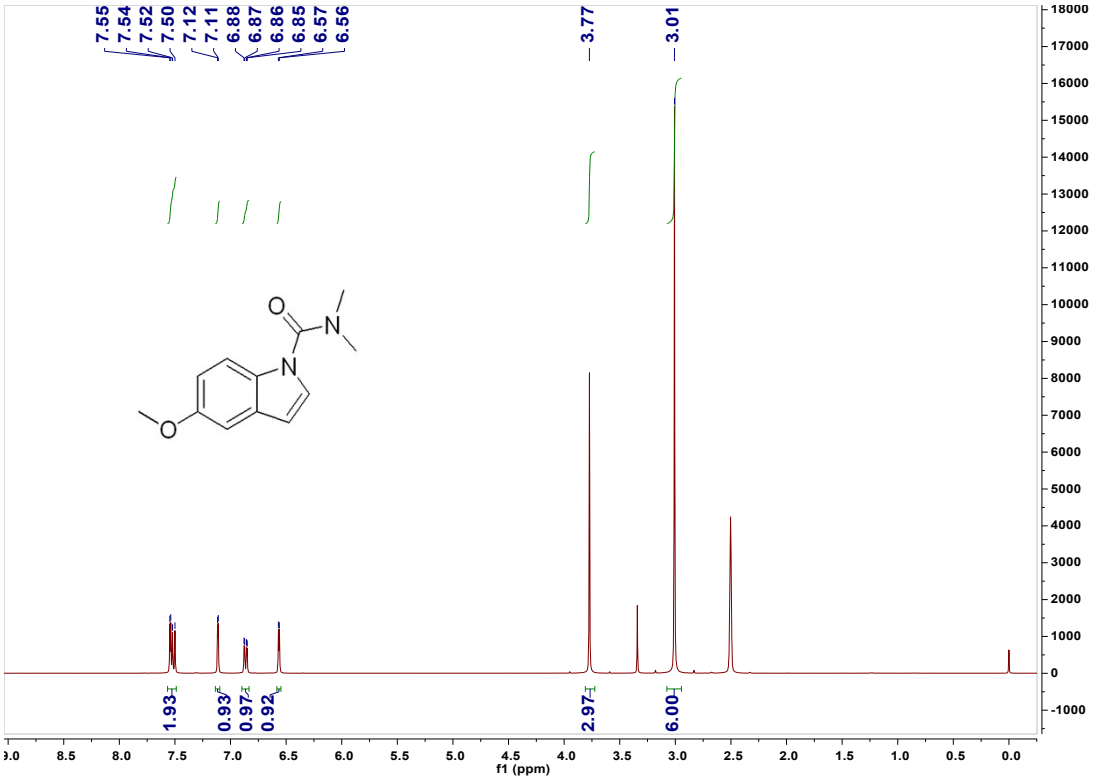
^{1}H NMR Spectrum (400 MHz, DMSO-*d6*) of **1a**



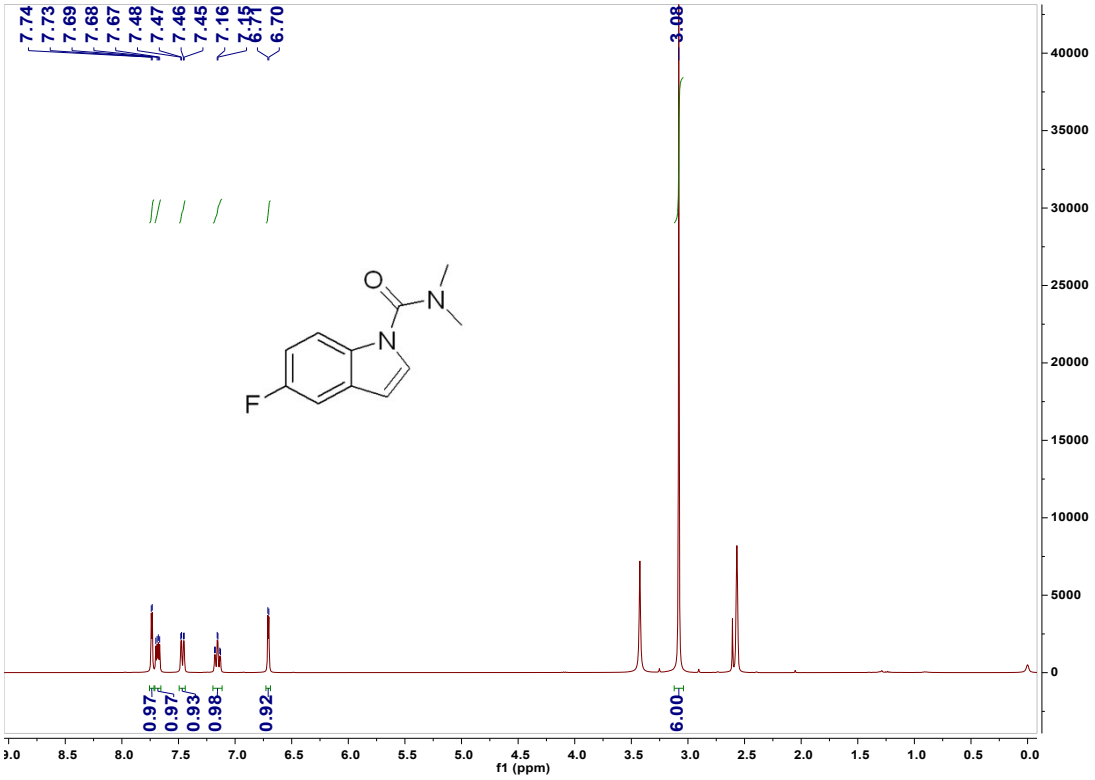
^{1}H NMR Spectrum (400 MHz, DMSO-d_6) of **1b**



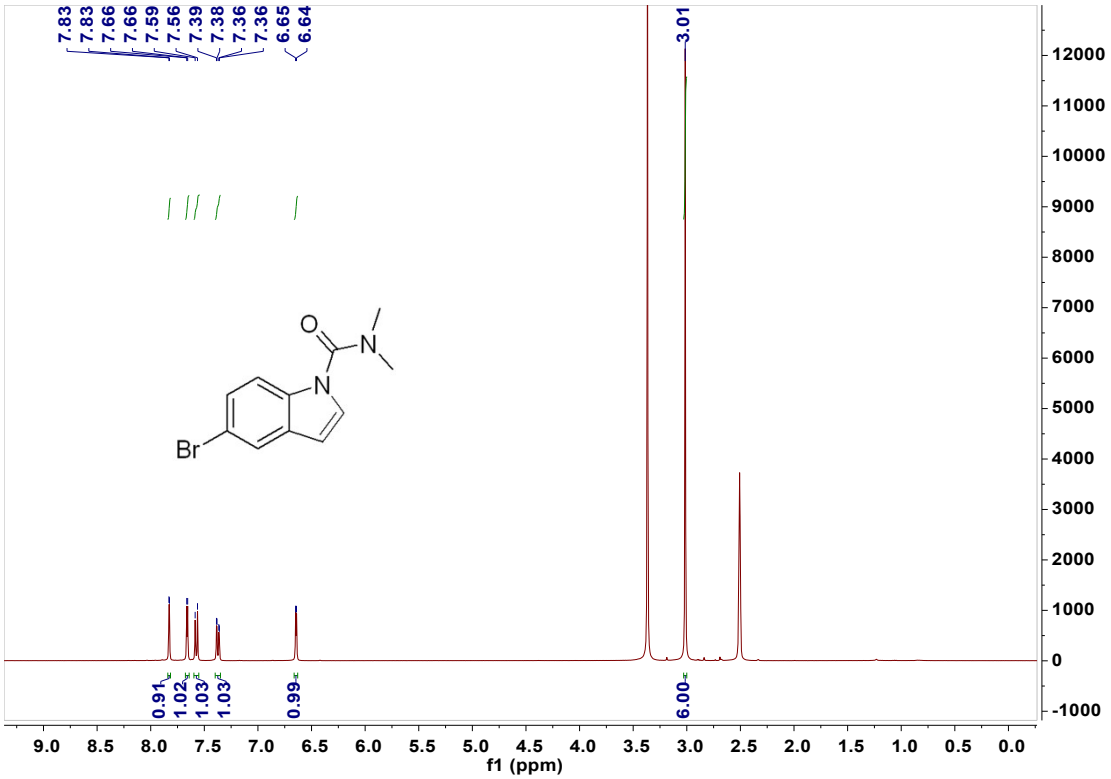
^{1}H NMR Spectrum (400 MHz, DMSO-d_6) of **1c**



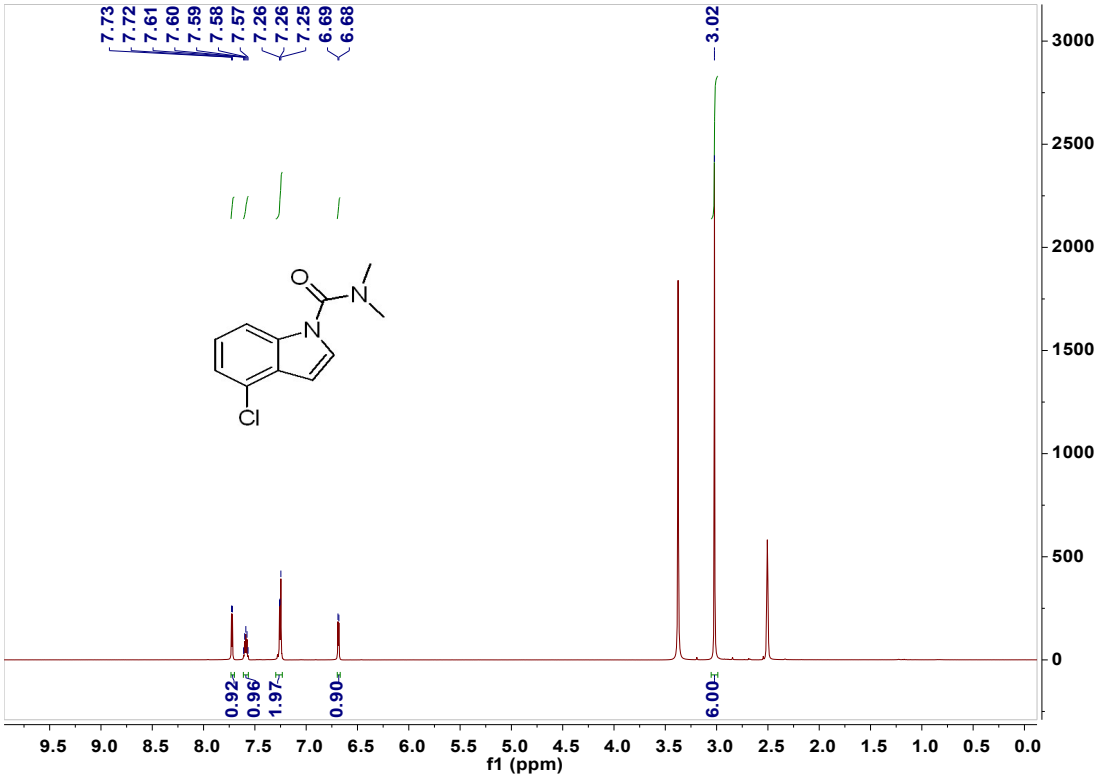
^{1}H NMR Spectrum (400 MHz, DMSO-d_6) of **1d**



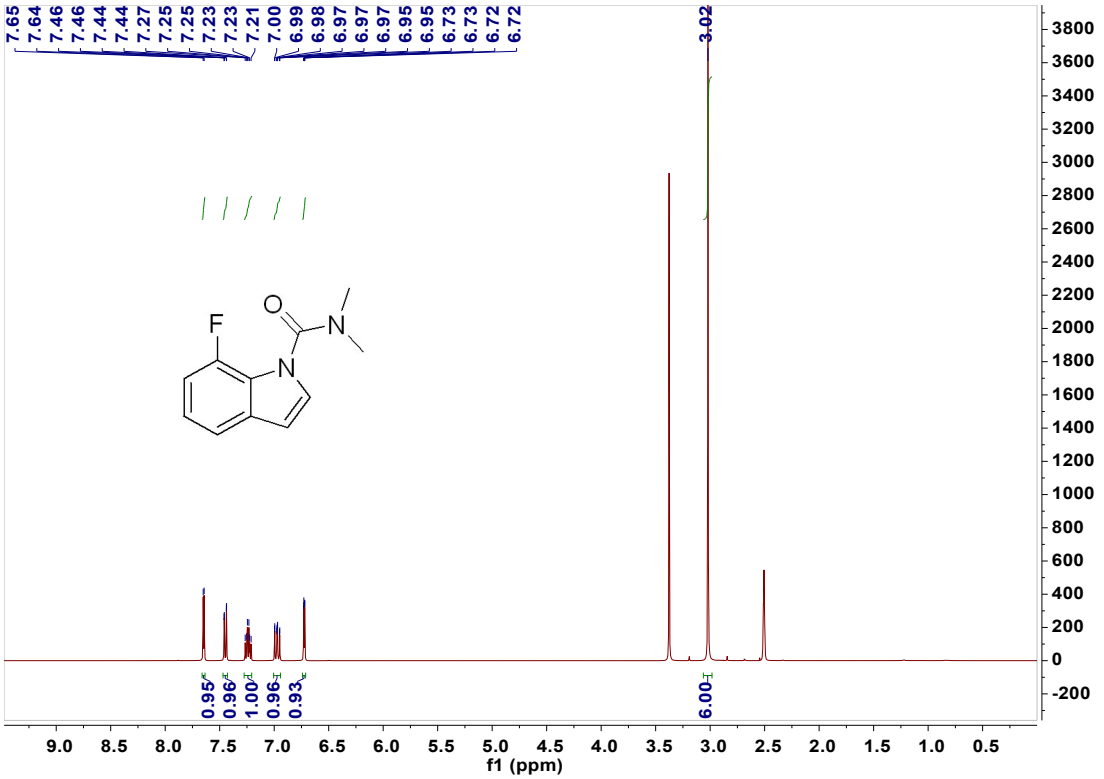
^{1}H NMR Spectrum (400 MHz, DMSO-d_6) of **1e**



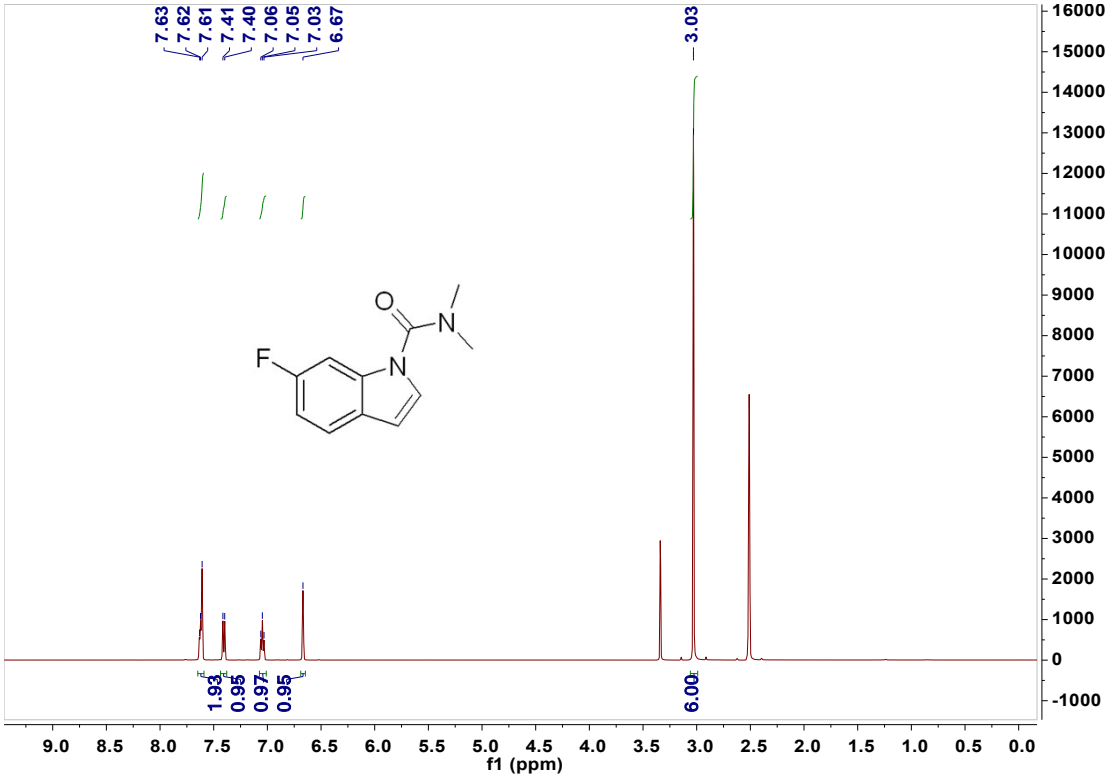
^{1}H NMR Spectrum (400 MHz, DMSO-d_6) of **1f**



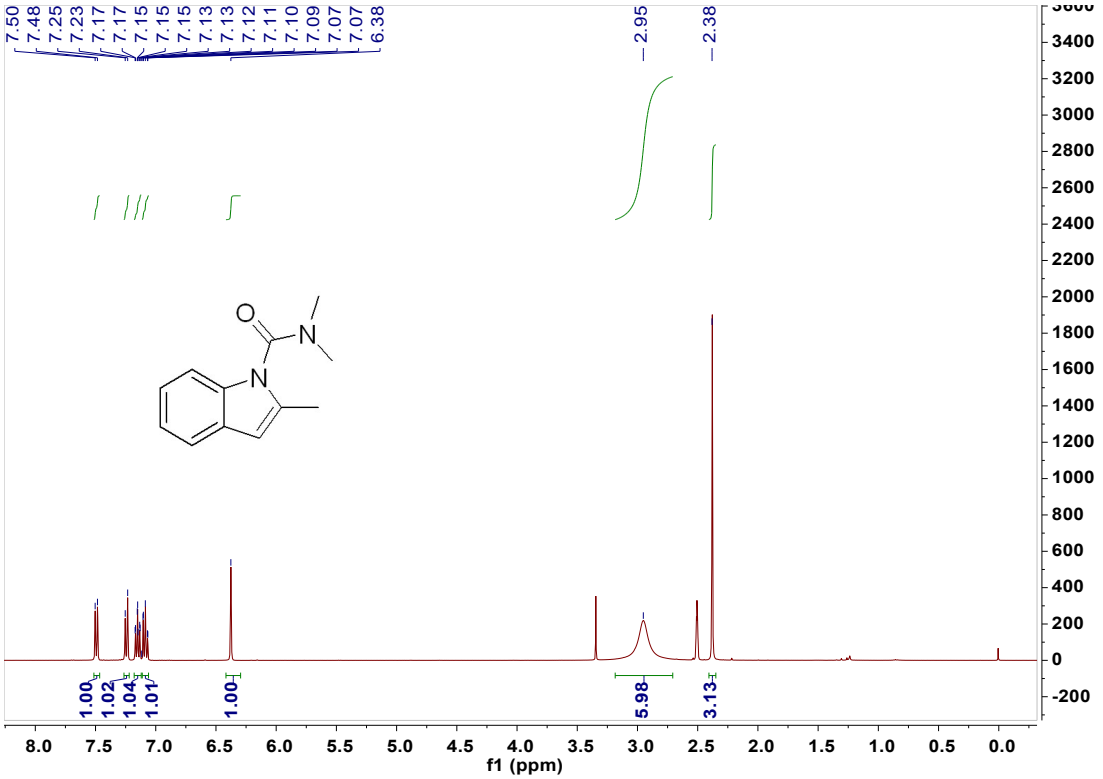
^{1}H NMR Spectrum (400 MHz, DMSO-d_6) of **1g**



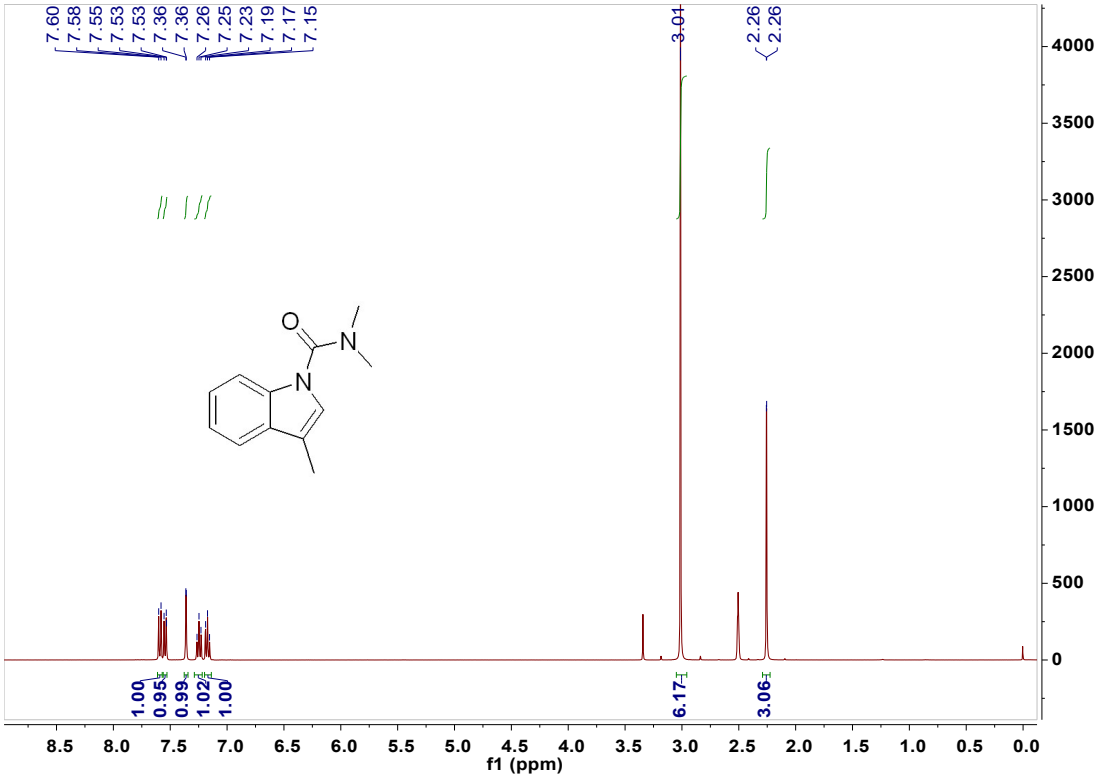
^{1}H NMR Spectrum (400 MHz, DMSO-d_6) of **1h**



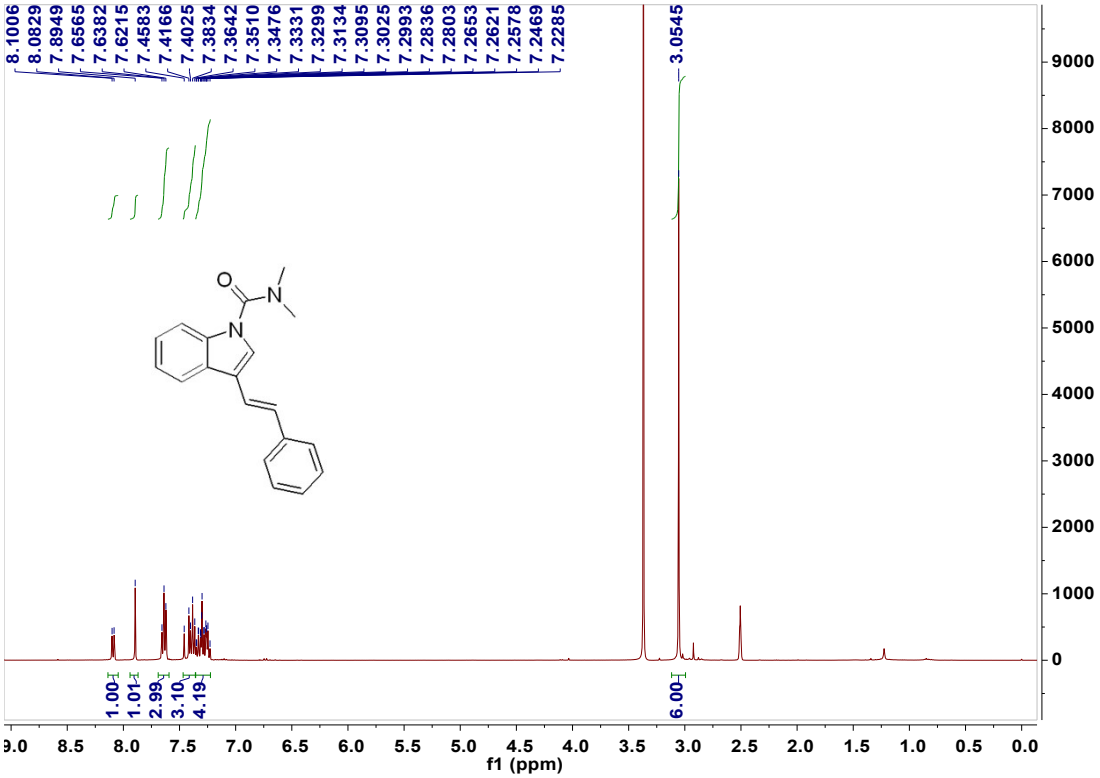
^{1}H NMR Spectrum (400 MHz, DMSO-d_6) of **1i**



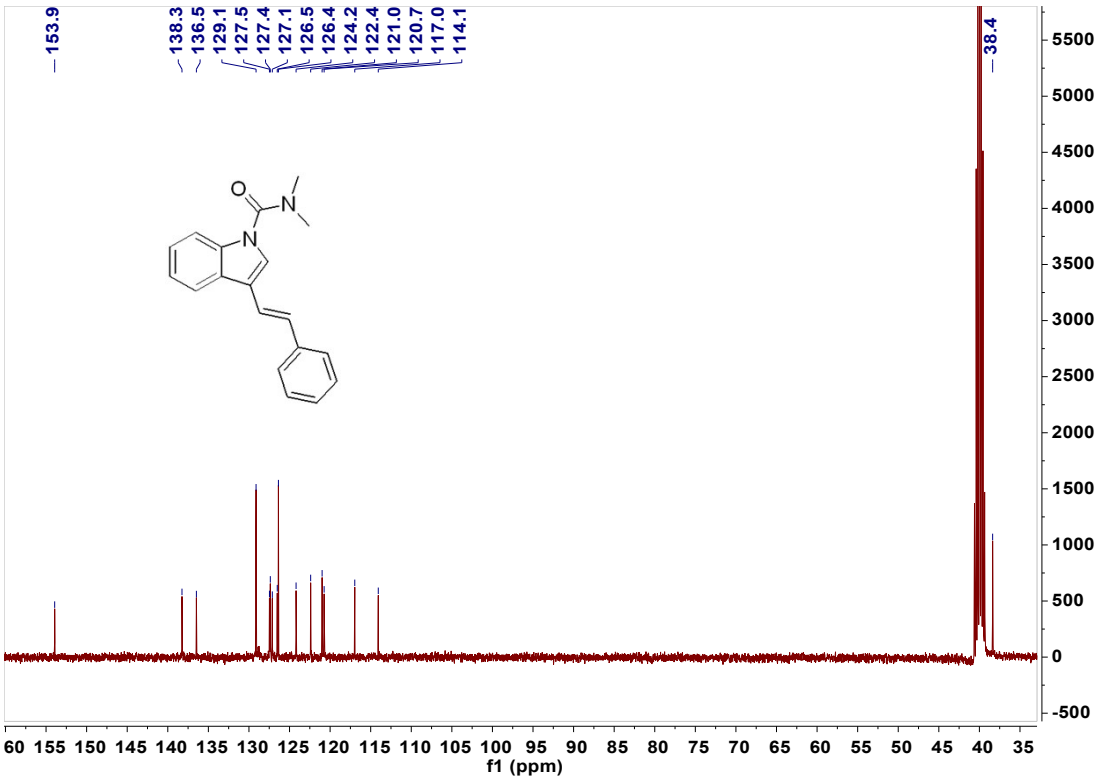
^{1}H NMR Spectrum (400 MHz, DMSO-d_6) of **1j**



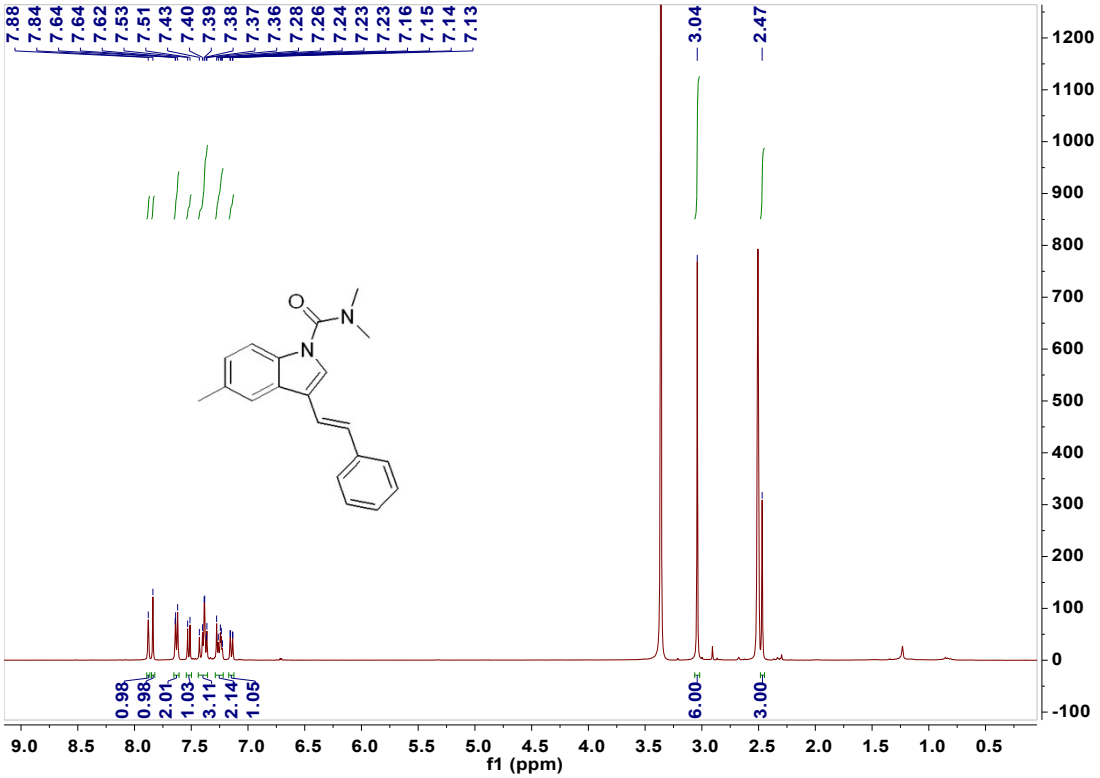
^{1}H NMR Spectrum (400 MHz, DMSO-d_6) of **3a**



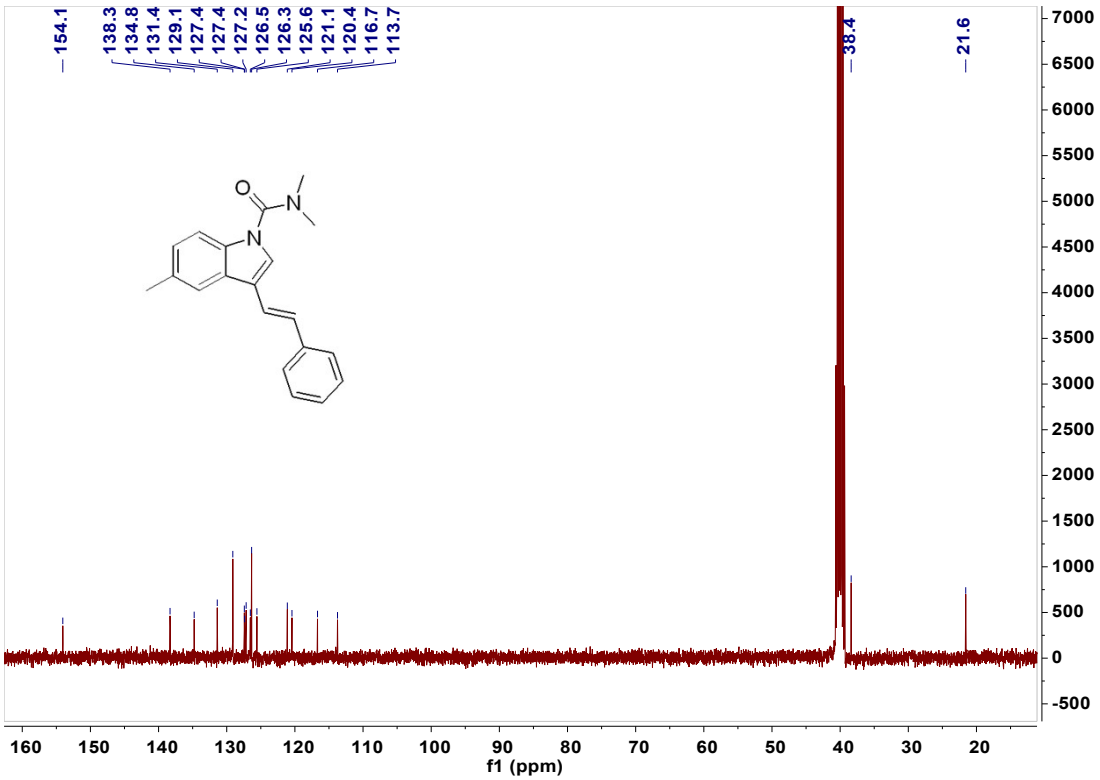
^{13}C NMR Spectrum (101 MHz, DMSO-d_6) of **3a**



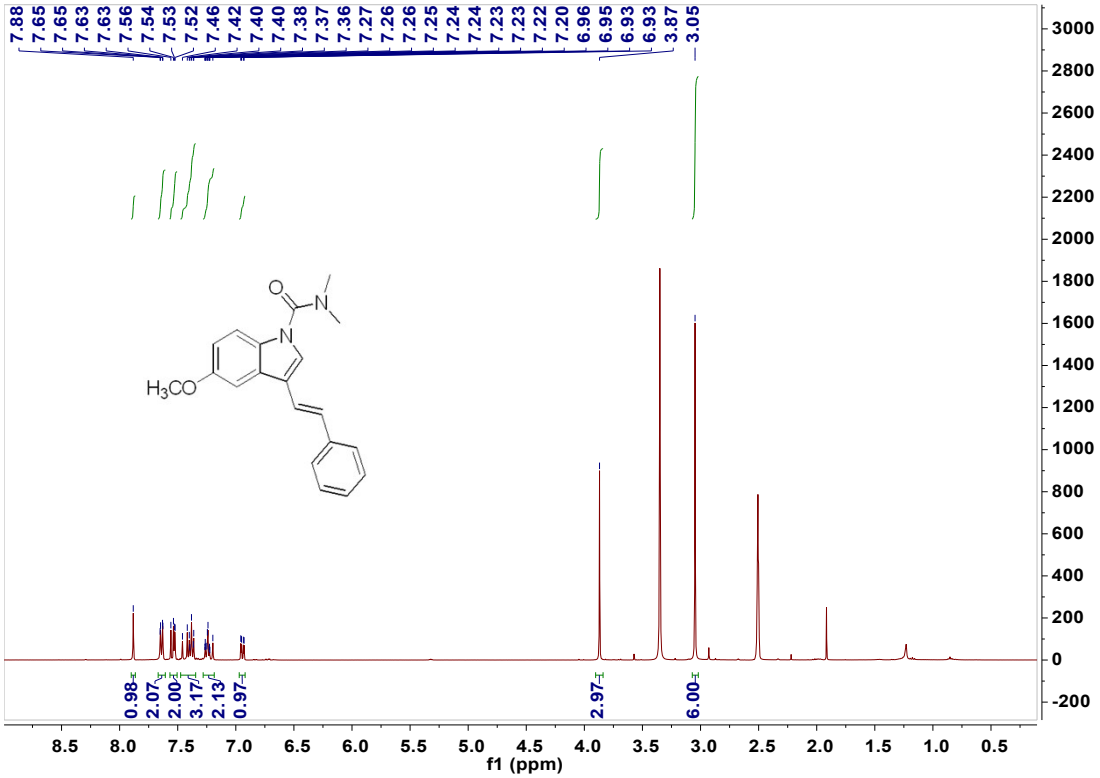
^{1}H NMR Spectrum (400 MHz, DMSO-d_6) of **3b**



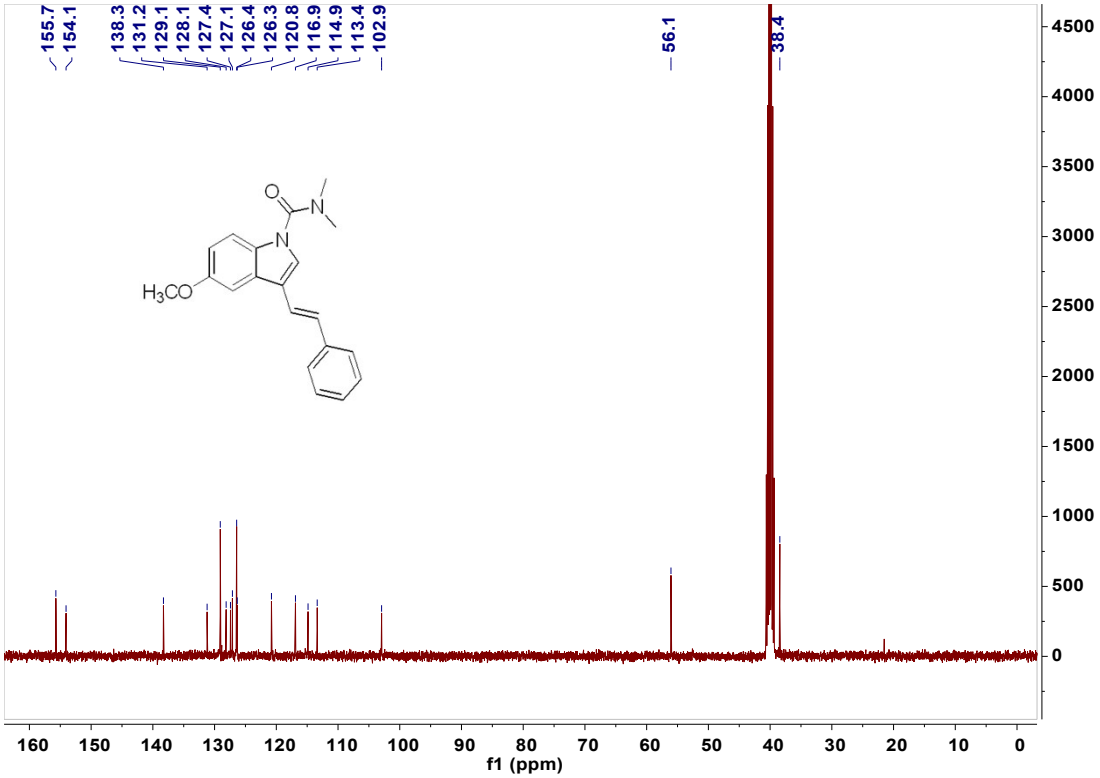
^{13}C NMR Spectrum (101 MHz, DMSO-d_6) of **3b**



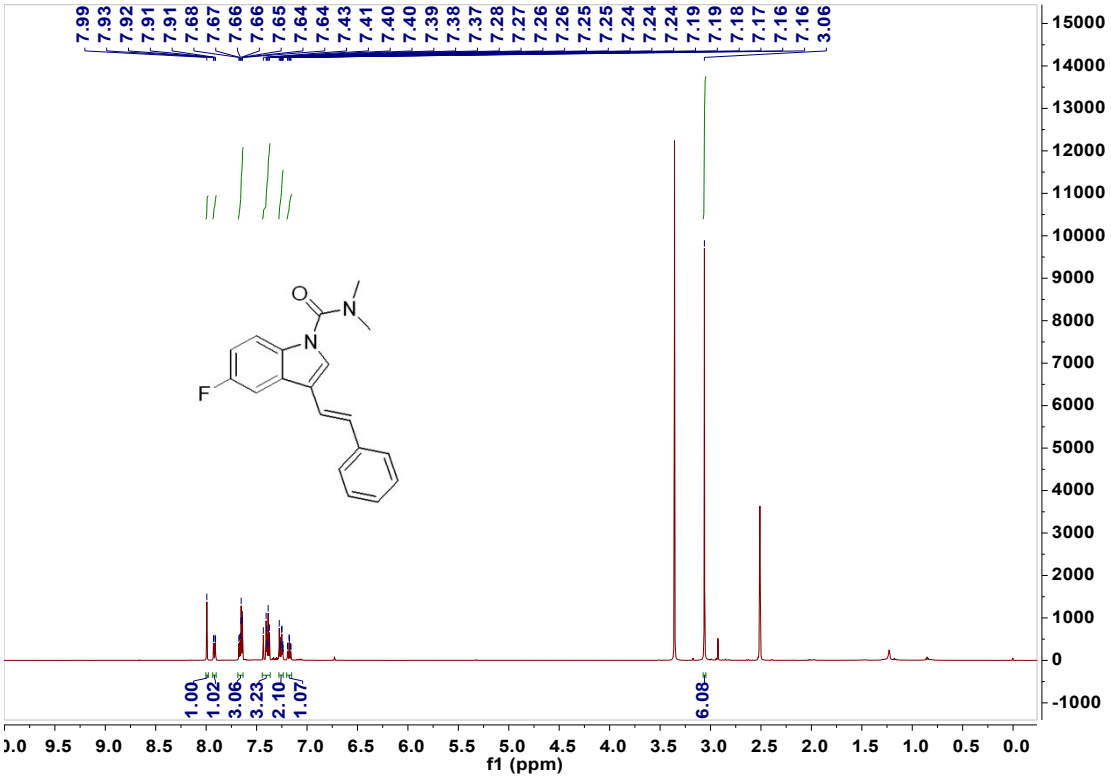
^{1}H NMR Spectrum (400 MHz, DMSO-d_6) of **3c**



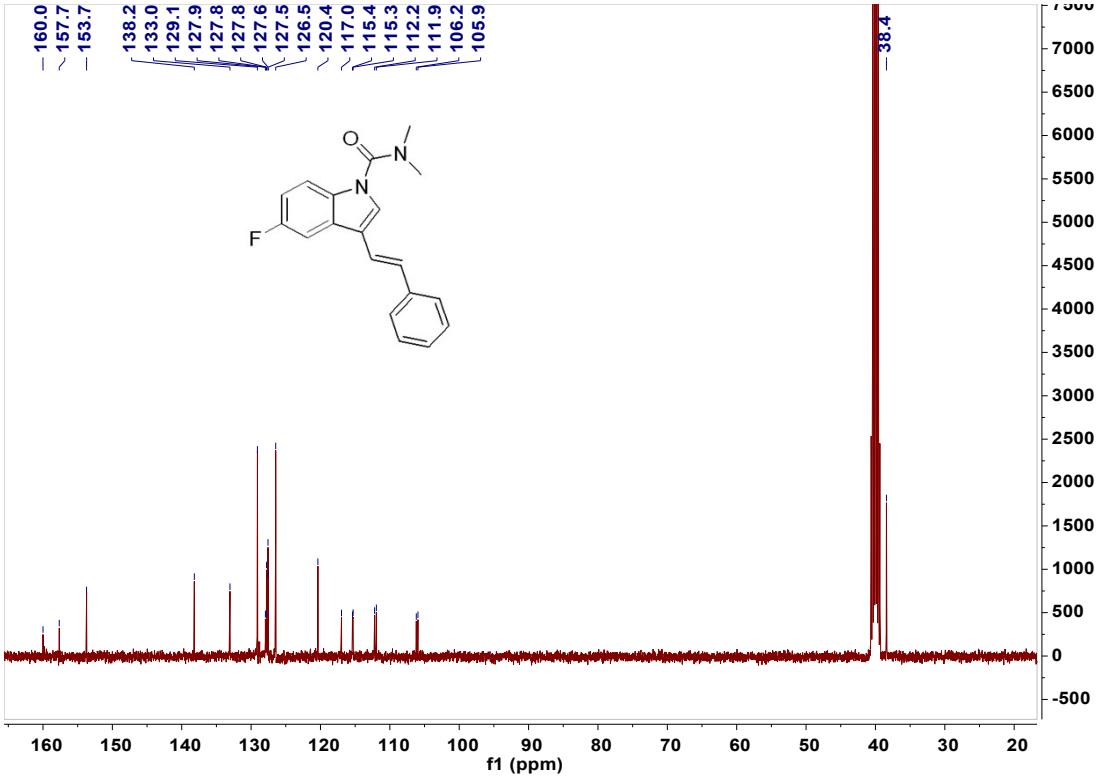
^{13}C NMR Spectrum (101 MHz, DMSO-d_6) of **3c**



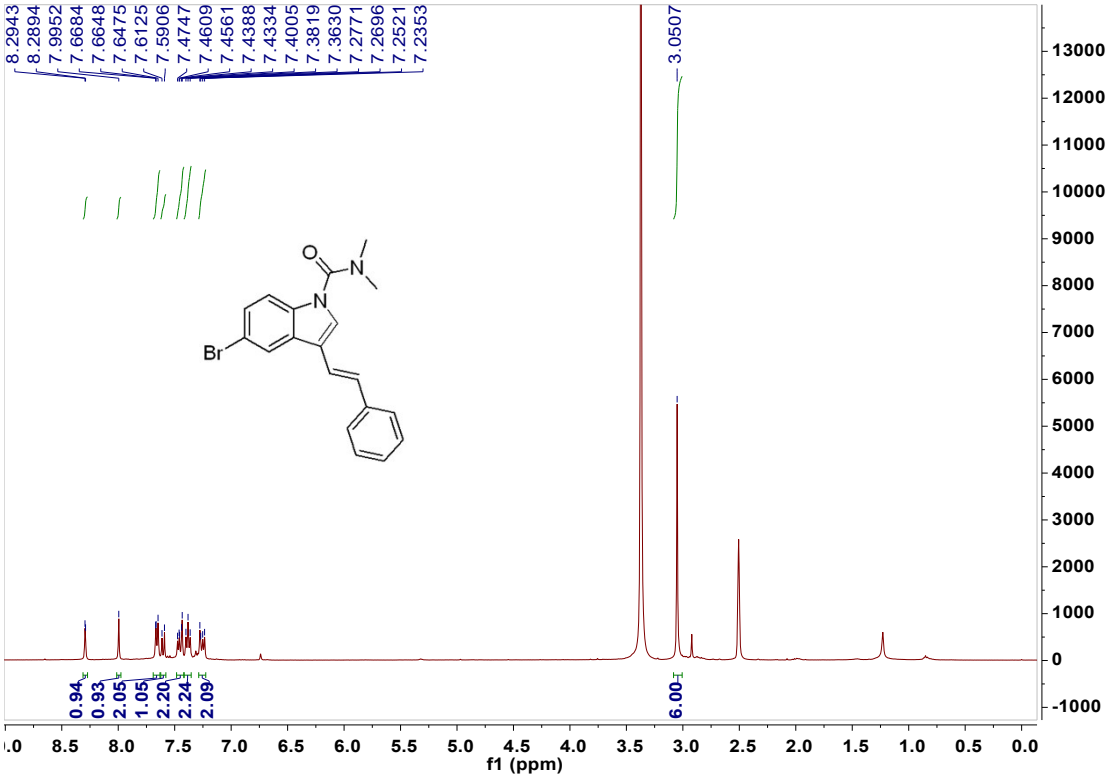
^{1}H NMR Spectrum (600 MHz, DMSO-d_6) of **3d**



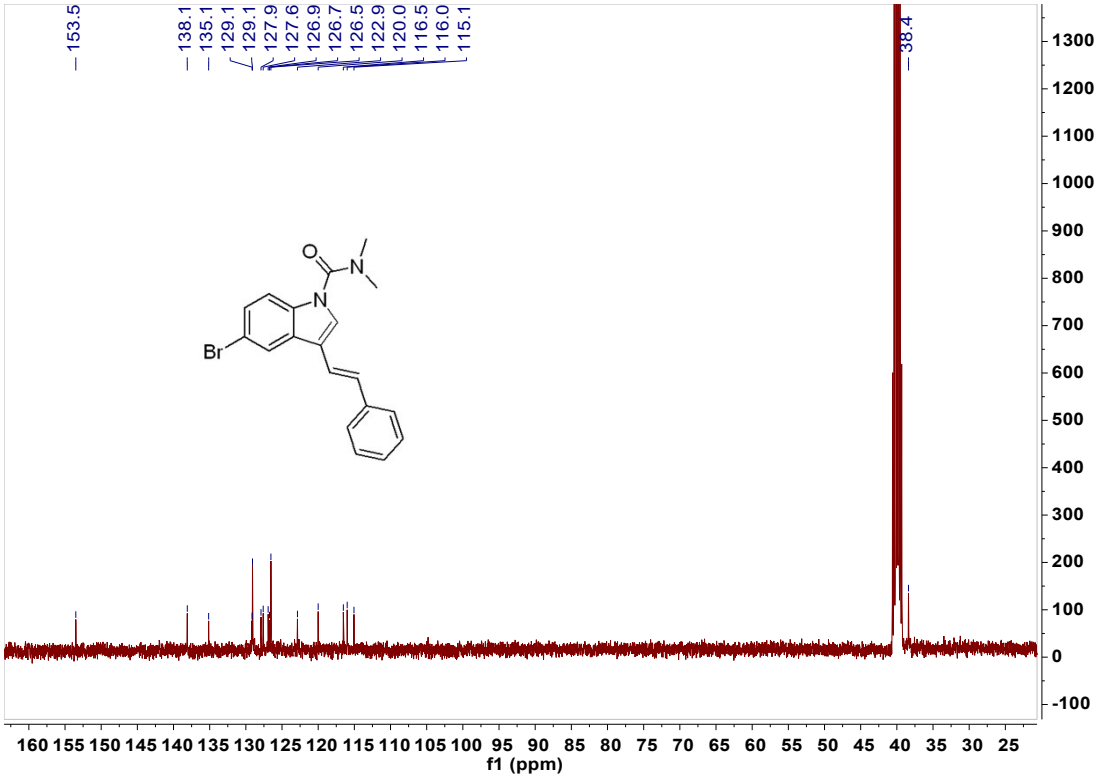
^{13}C NMR Spectrum (101 MHz, DMSO-d_6) of **3d**



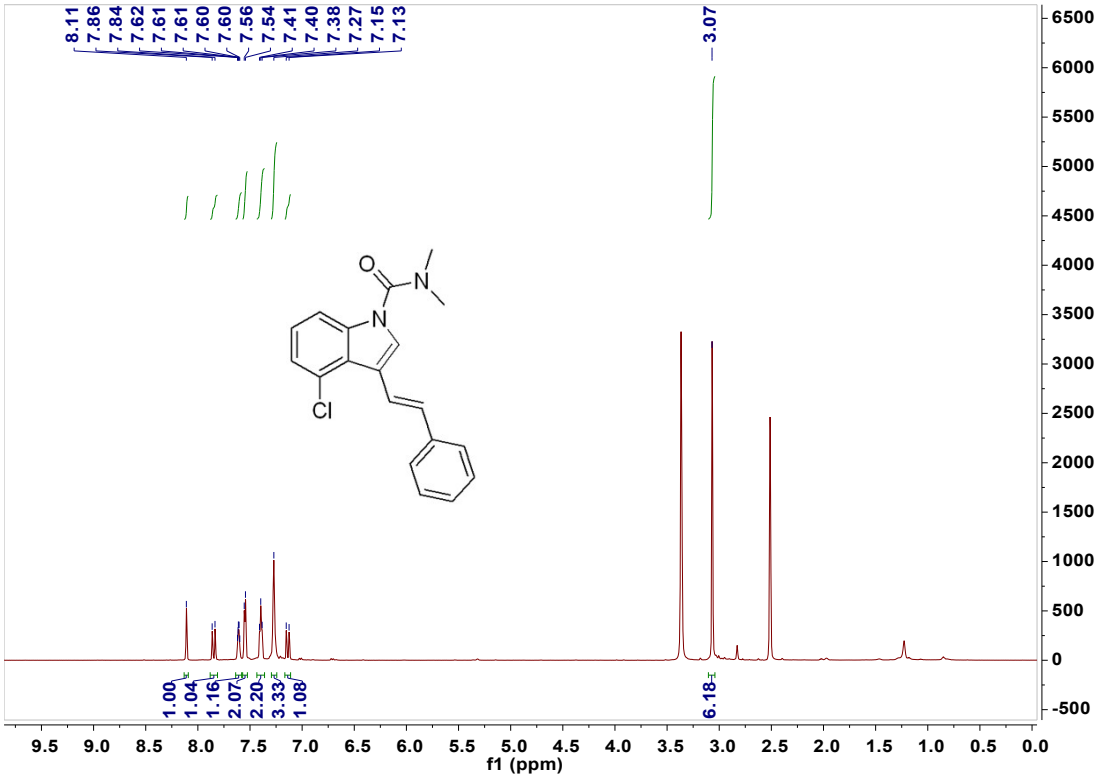
^{1}H NMR Spectrum (400 MHz, DMSO-d_6) of **3e**



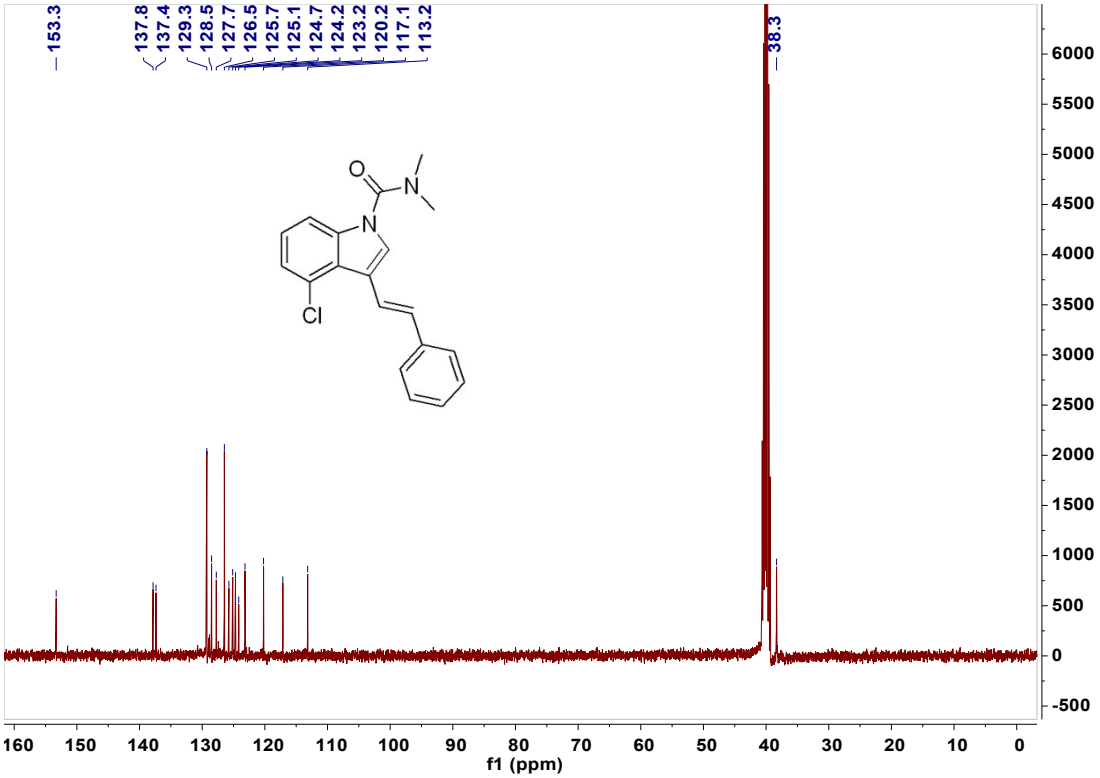
^{13}C NMR Spectrum (101 MHz, DMSO-d_6) of **3e**



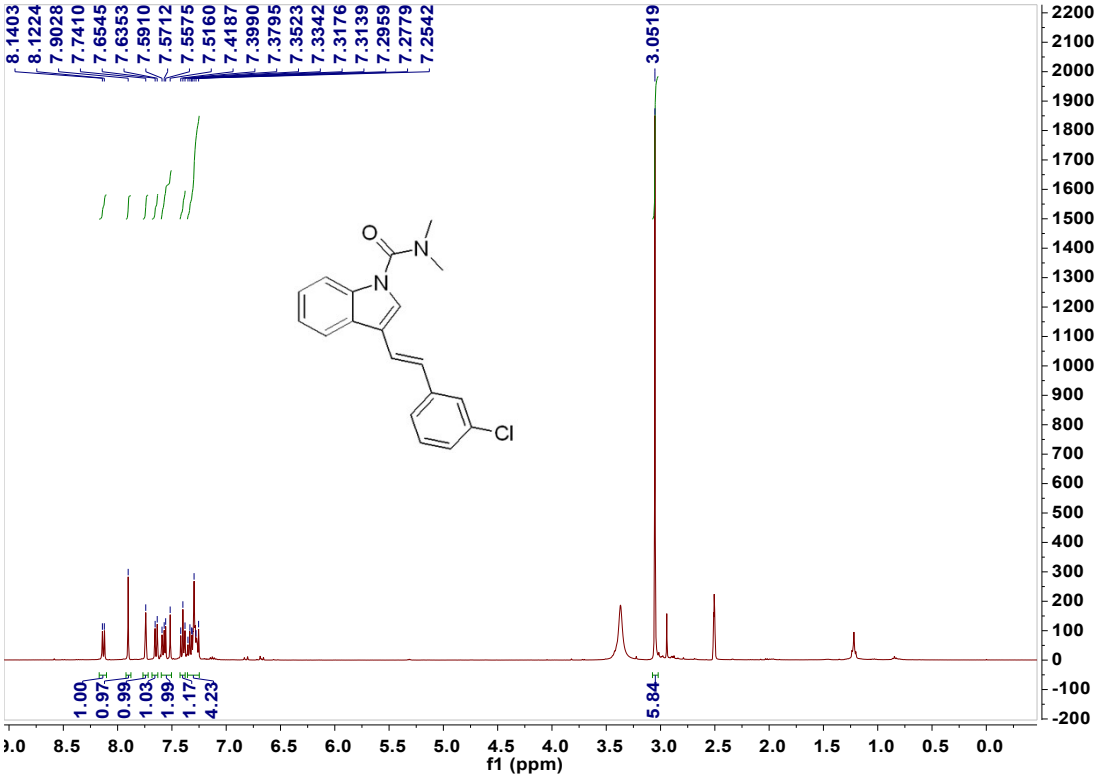
^{1}H NMR Spectrum (600 MHz, DMSO-d_6) of **3f**



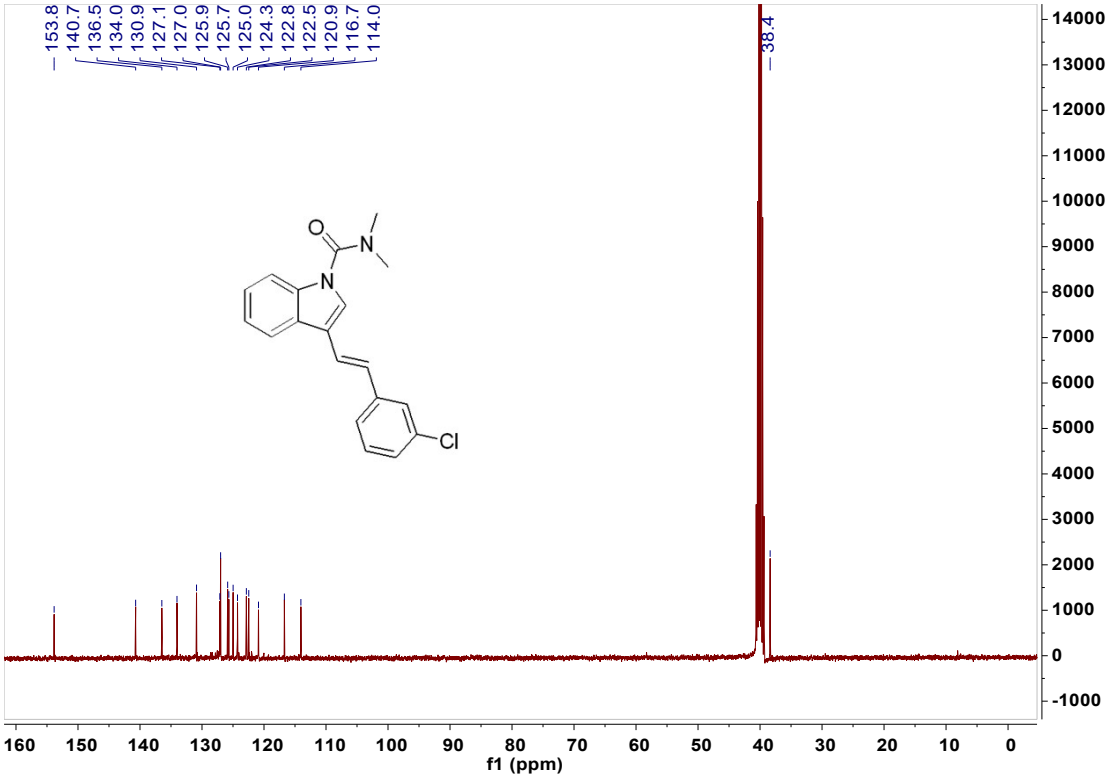
^{13}C NMR Spectrum (101MHz, DMSO-d_6) of **3f**



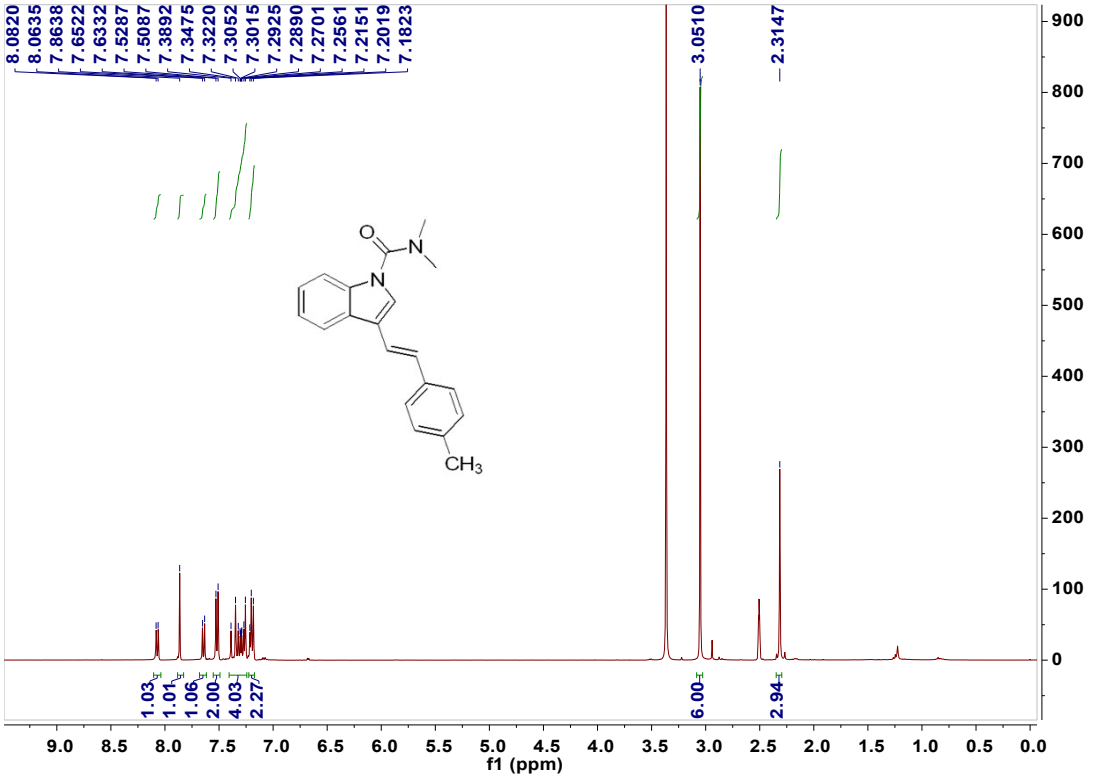
^{1}H NMR Spectrum (400 MHz, DMSO-d_6) of **3g**



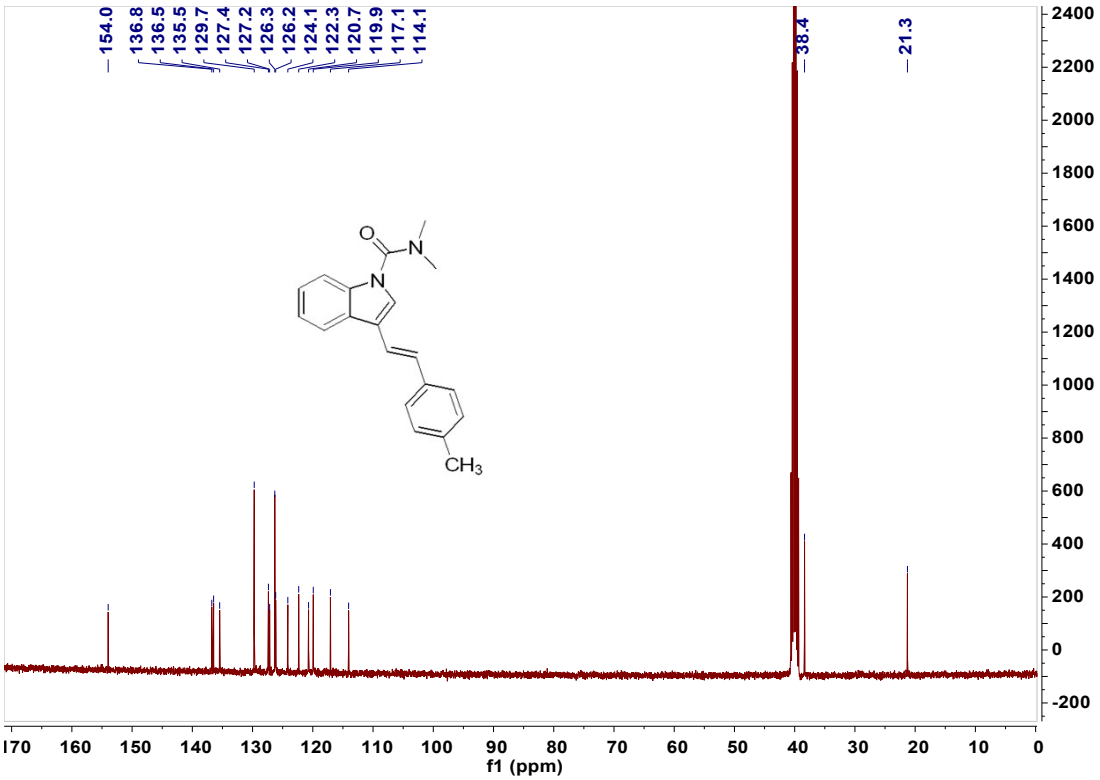
^{13}C NMR Spectrum (101 MHz, DMSO-d_6) of **3g**



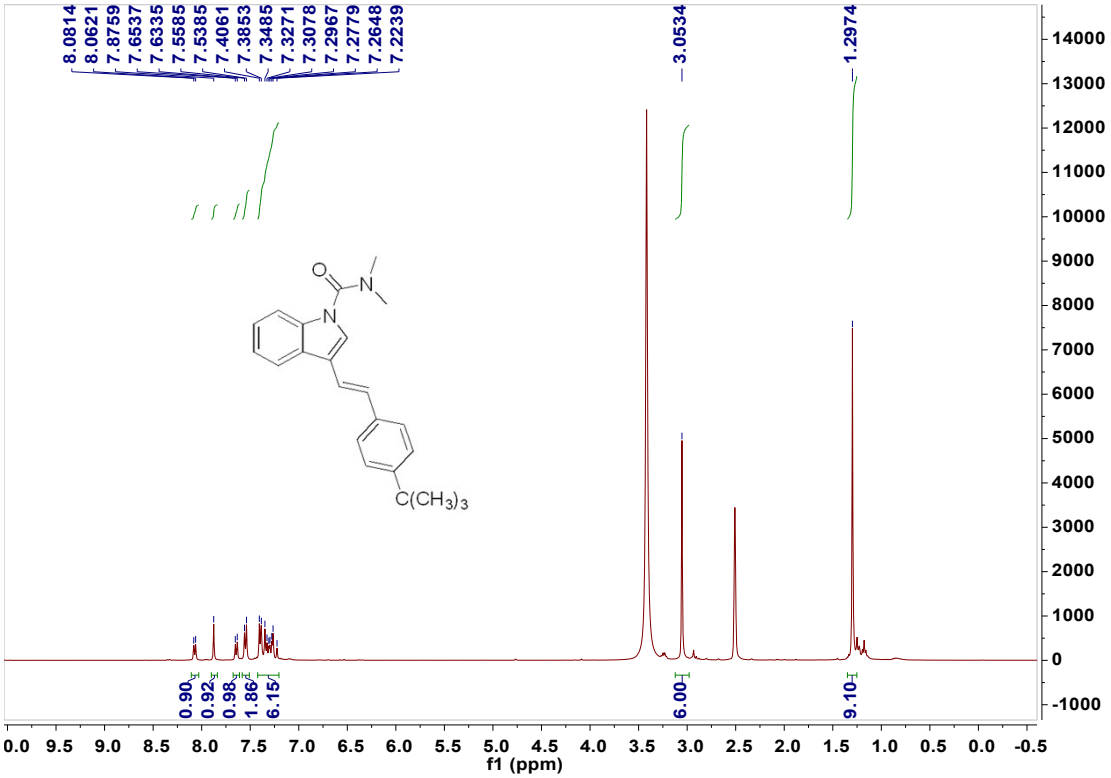
^{1}H NMR Spectrum (400 MHz, DMSO-d_6) of **3h**



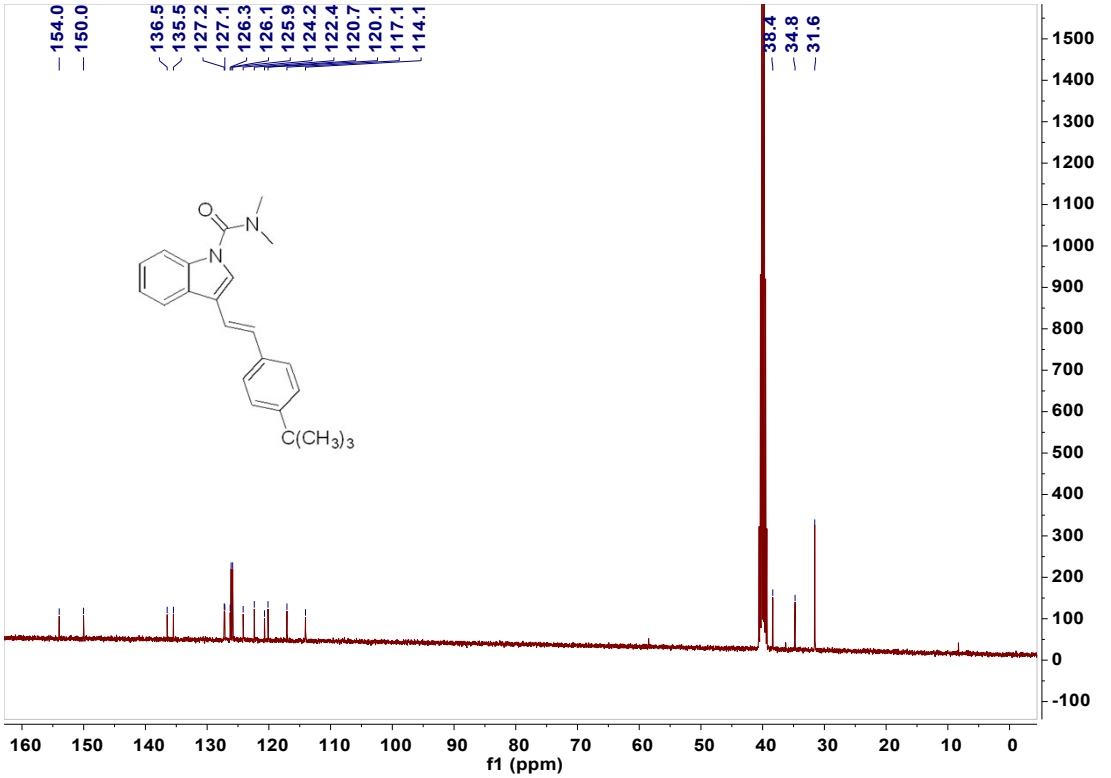
^{13}C NMR Spectrum (101 MHz, DMSO-d_6) of **3h**



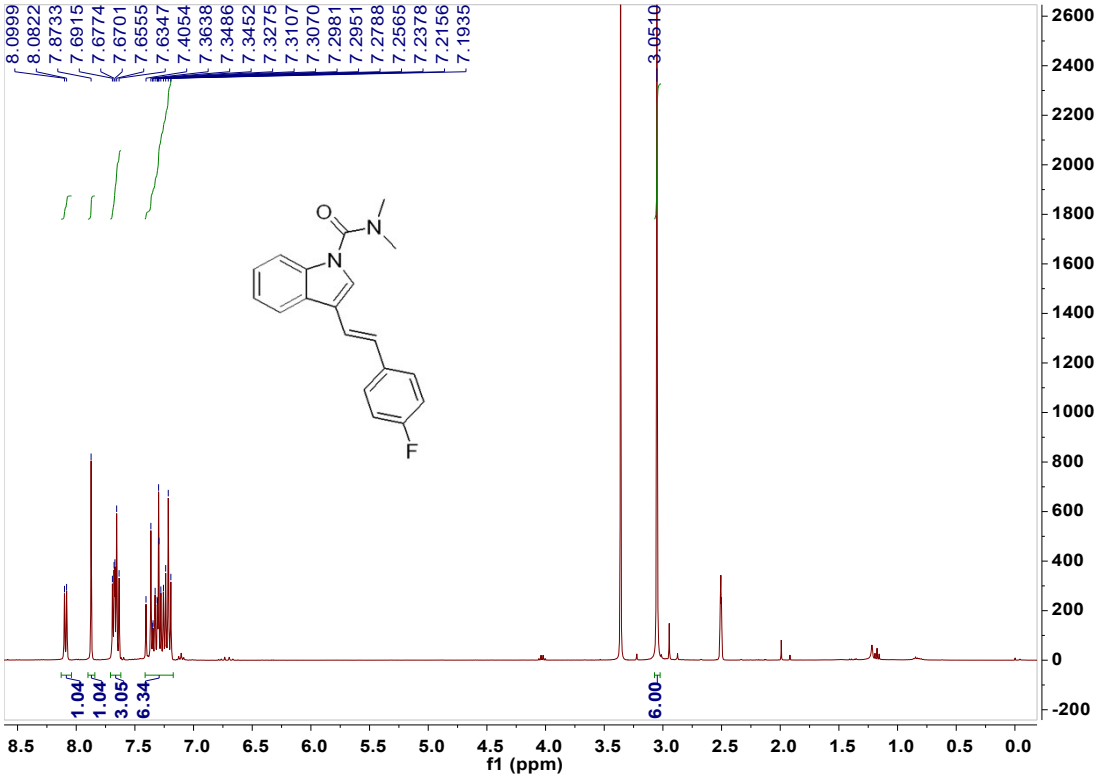
^{1}H NMR Spectrum (400 MHz, DMSO-d_6) of **3i**



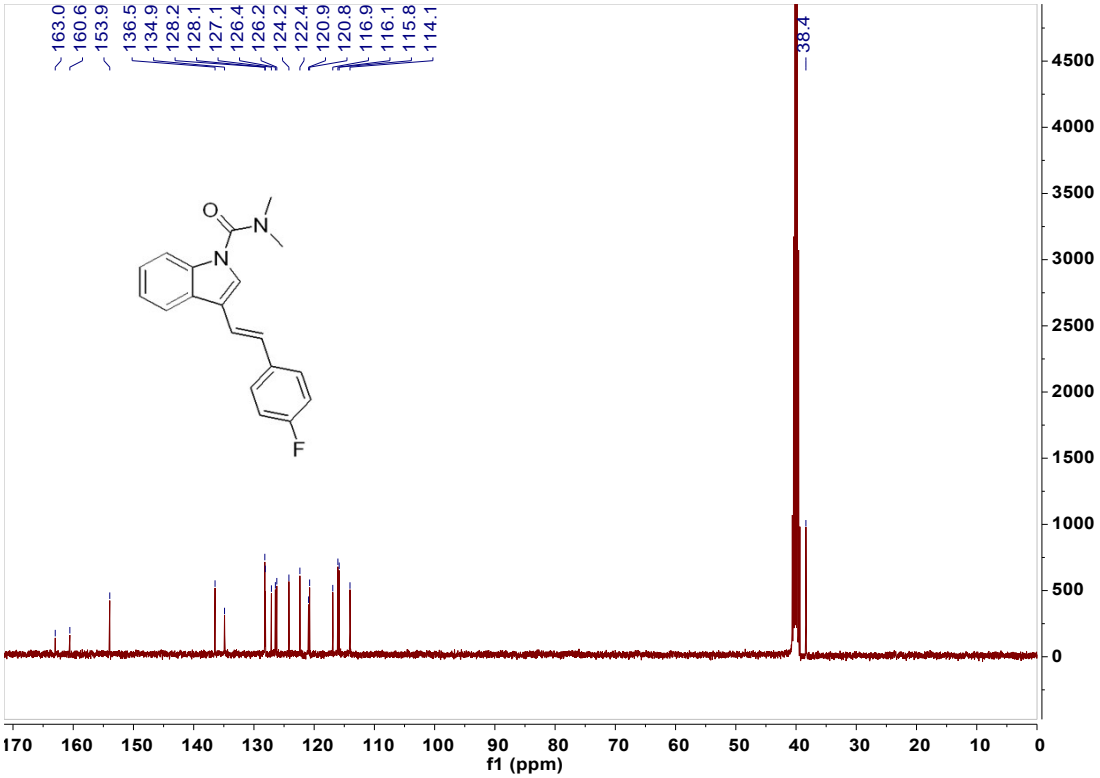
^{13}C NMR Spectrum (101 MHz, DMSO-d_6) of **3i**



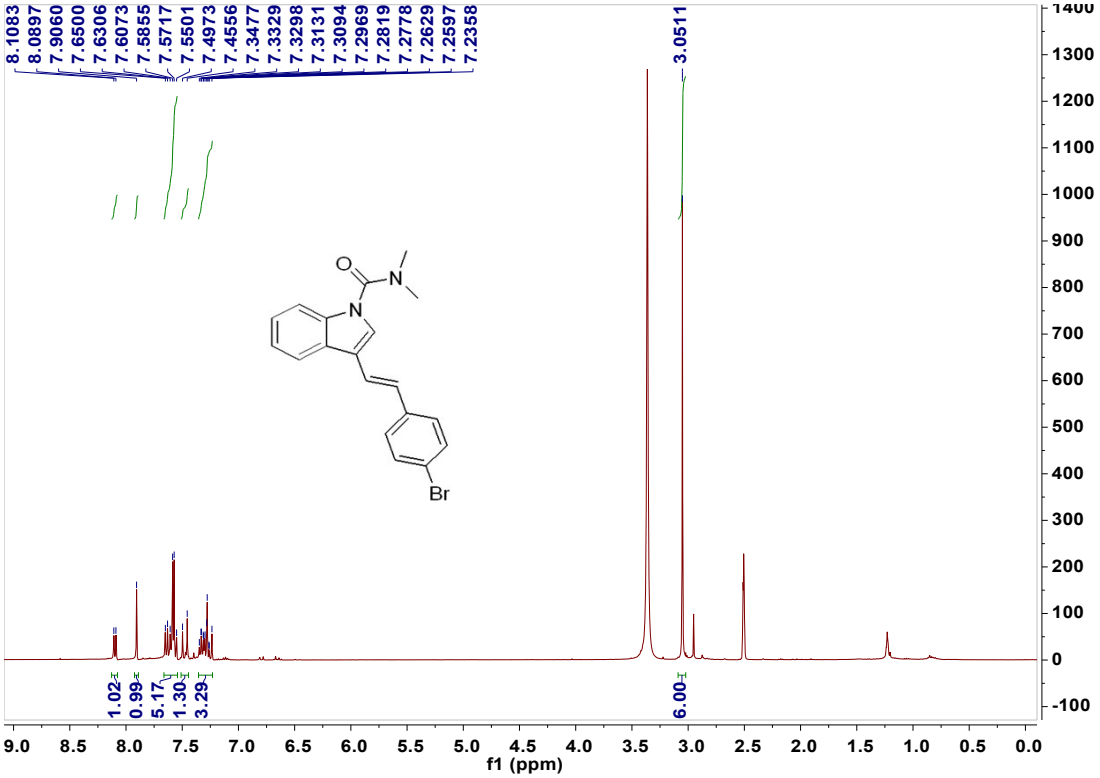
^{1}H NMR Spectrum (400 MHz, DMSO-d_6) of **3j**



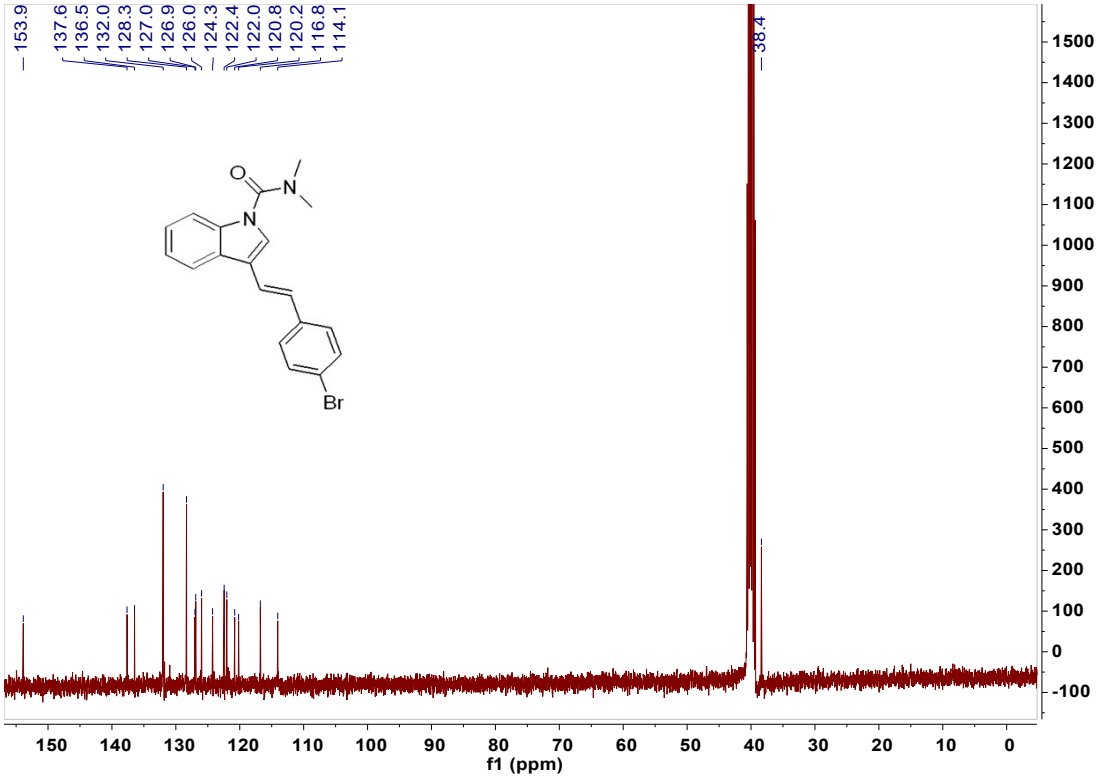
^{13}C NMR Spectrum (101 MHz, DMSO-d_6) of **3j**



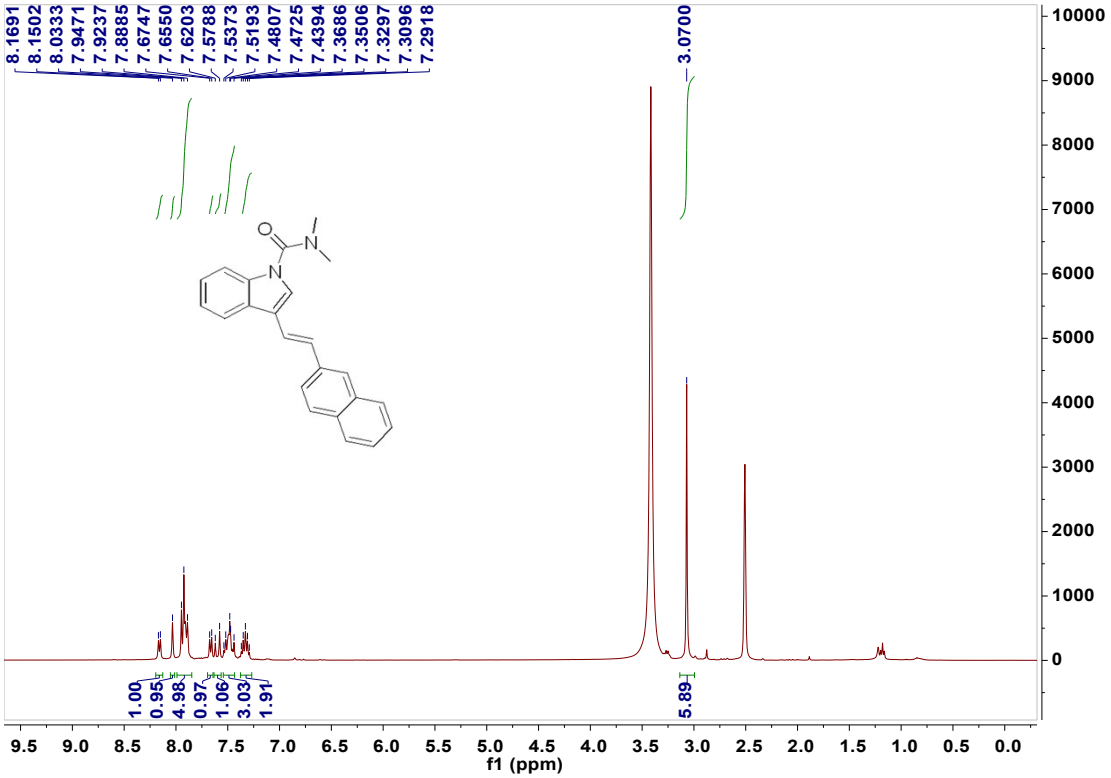
^{1}H NMR Spectrum (400 MHz, DMSO-d_6) of **3k**



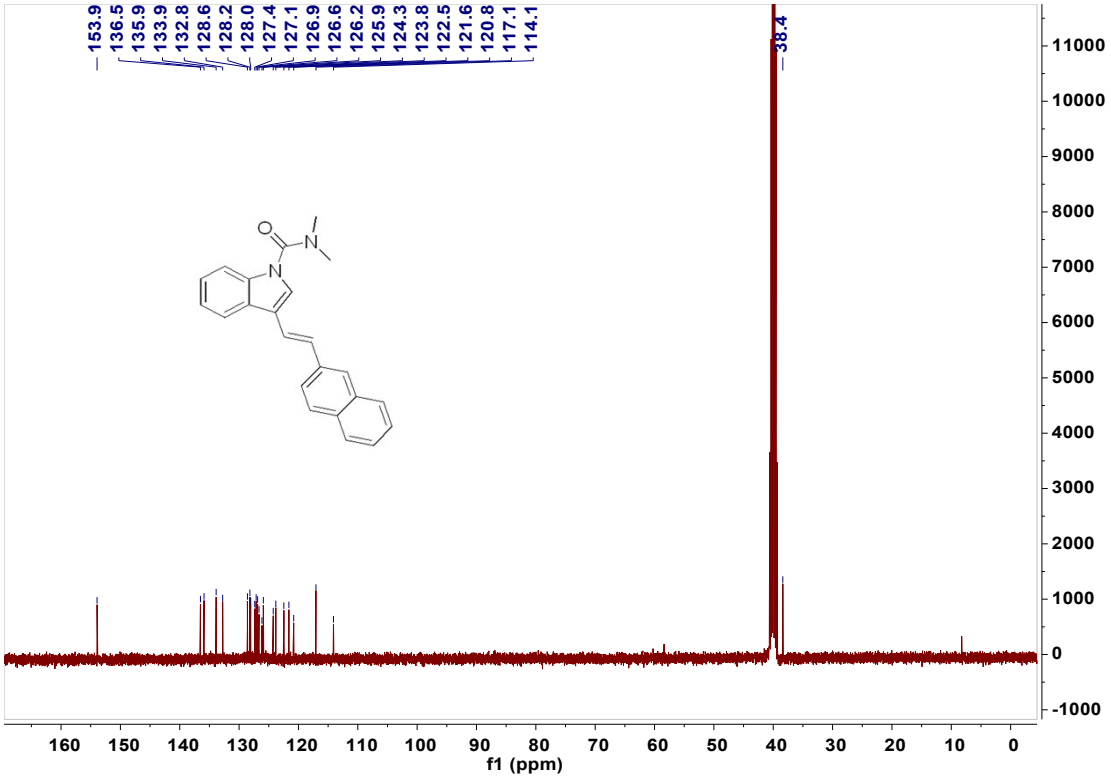
^{13}C NMR Spectrum (101 MHz, DMSO-d_6) of **3k**



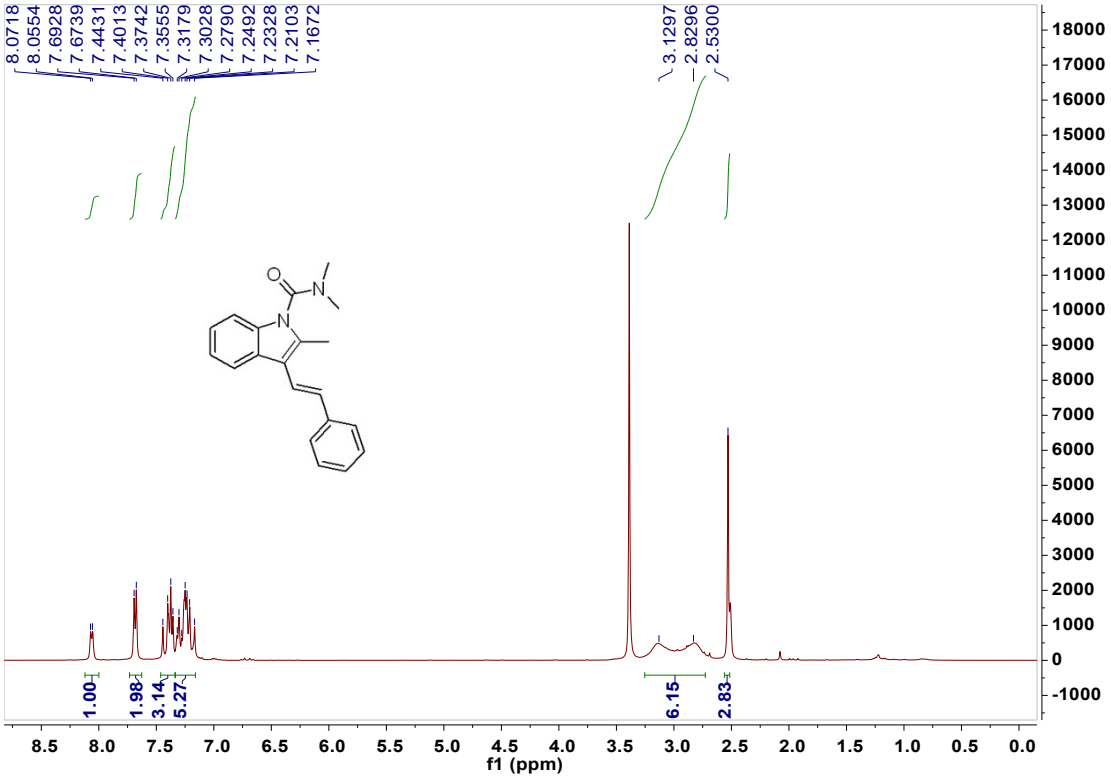
^{1}H NMR Spectrum (400 MHz, DMSO-d_6) of **3l**



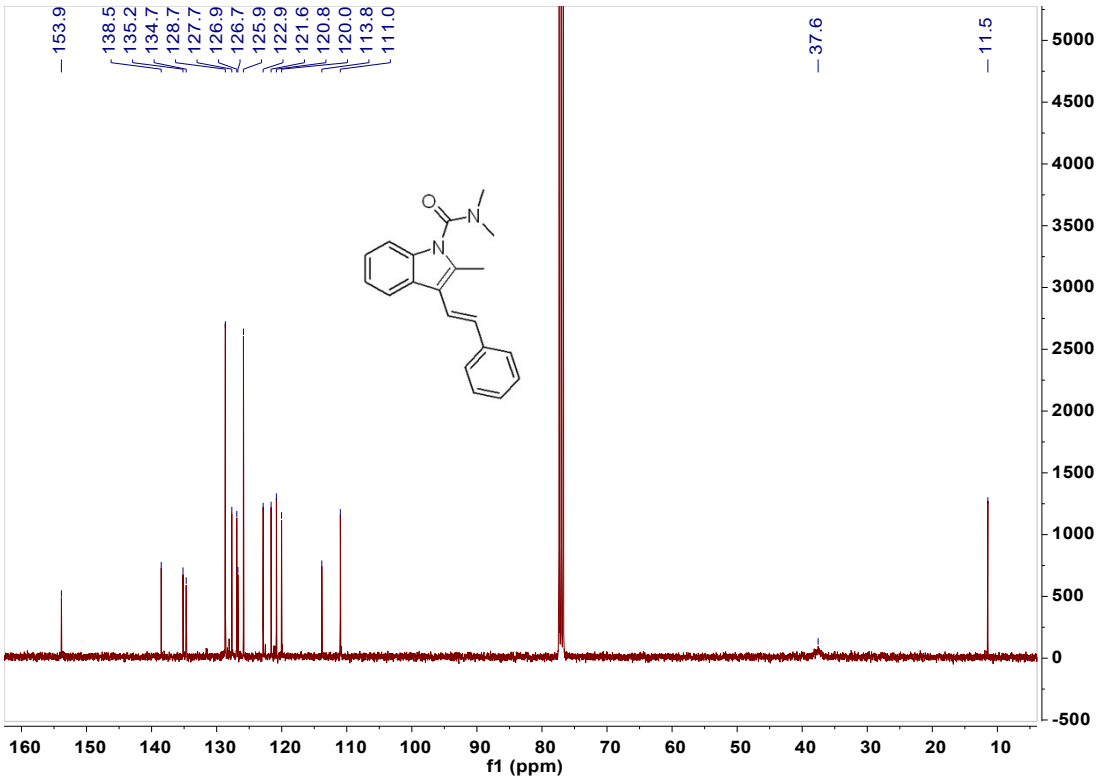
^{13}C NMR Spectrum (101 MHz, DMSO-d_6) of **3l**



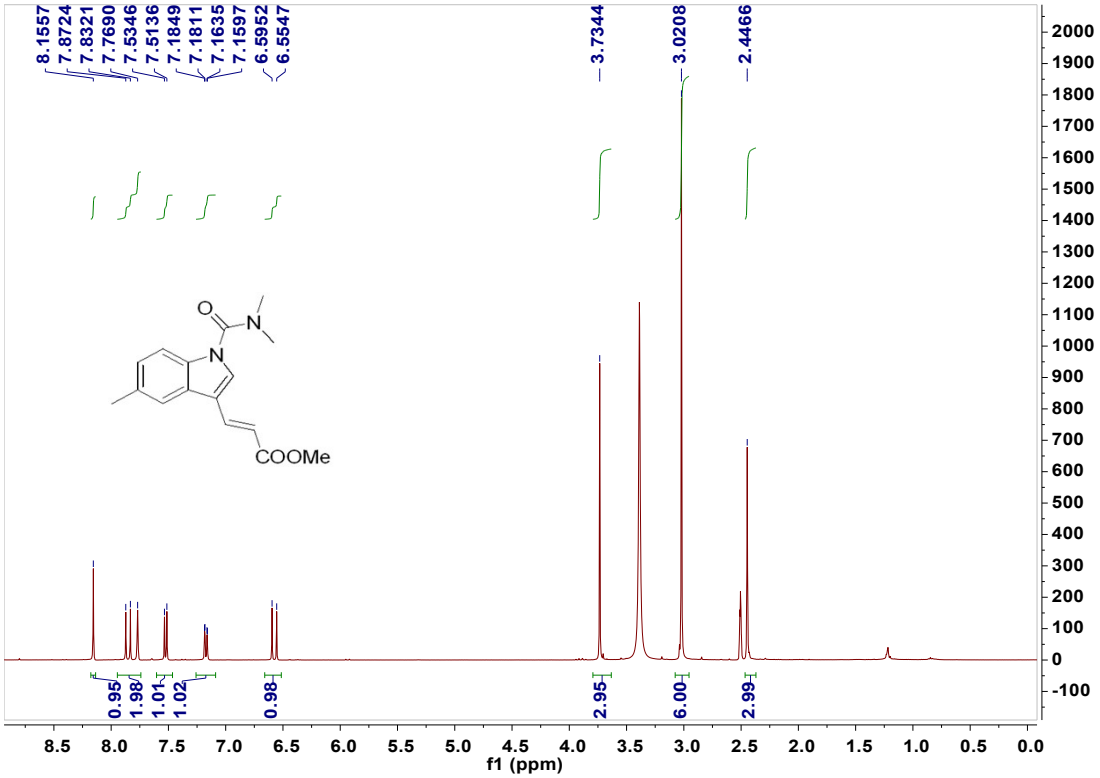
^{1}H NMR Spectrum (400 MHz, DMSO-d_6) of **3m**



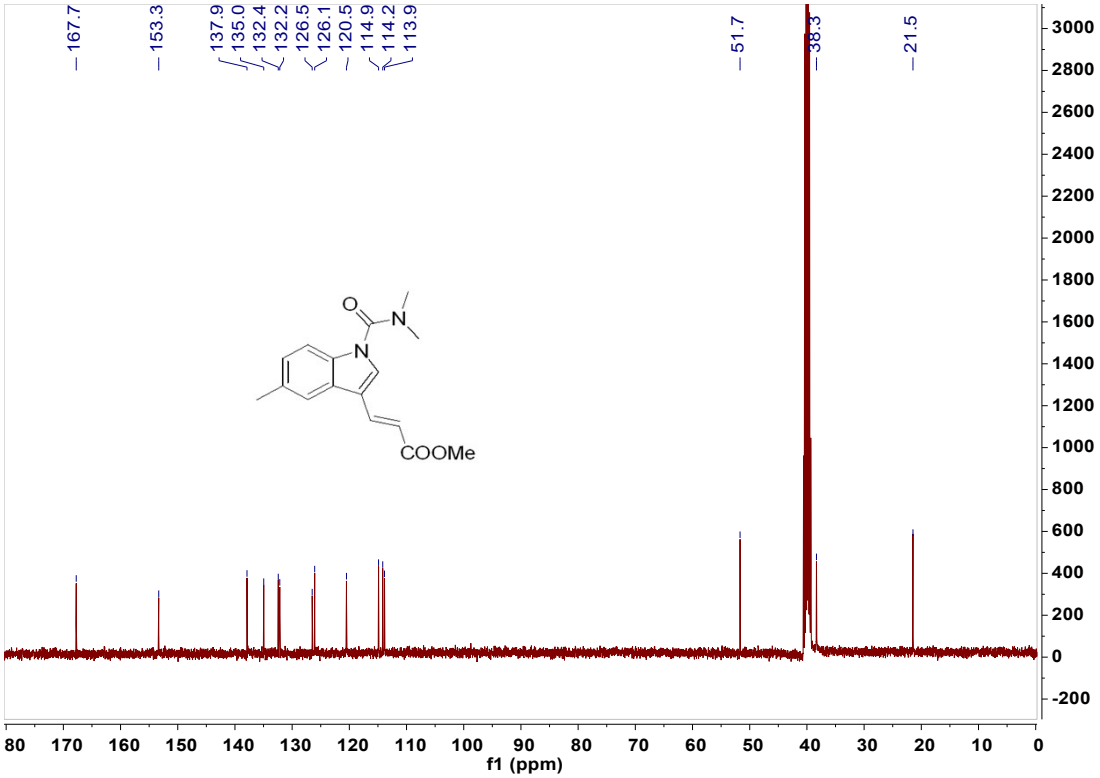
^{13}C NMR Spectrum (101 MHz, DMSO-d_6) of **3m**



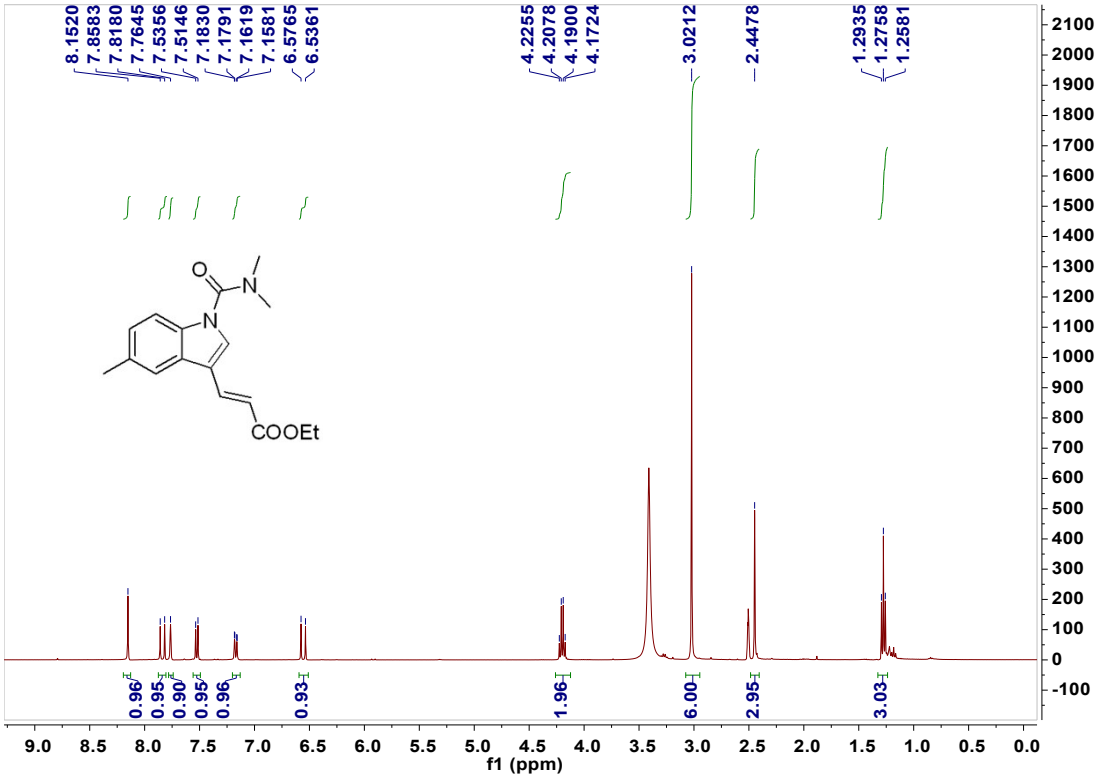
^{1}H NMR Spectrum (400 MHz, DMSO-d_6) of **5a**



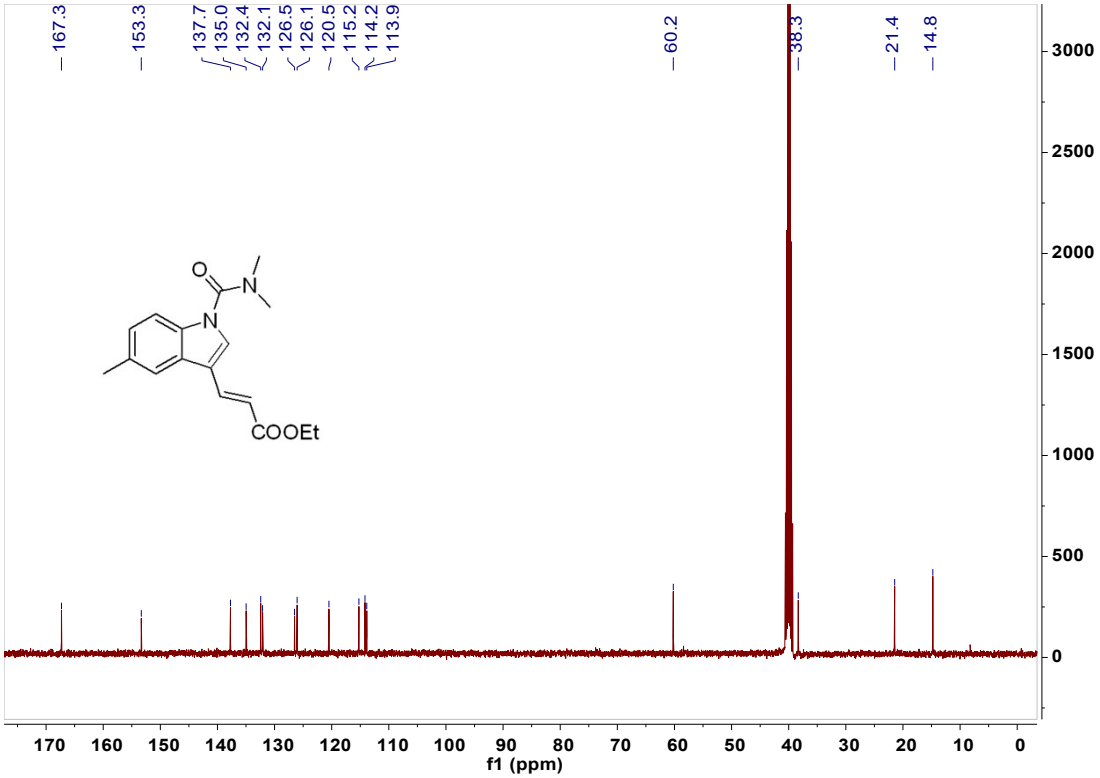
^{13}C NMR Spectrum (101 MHz, DMSO-d_6) of **5a**



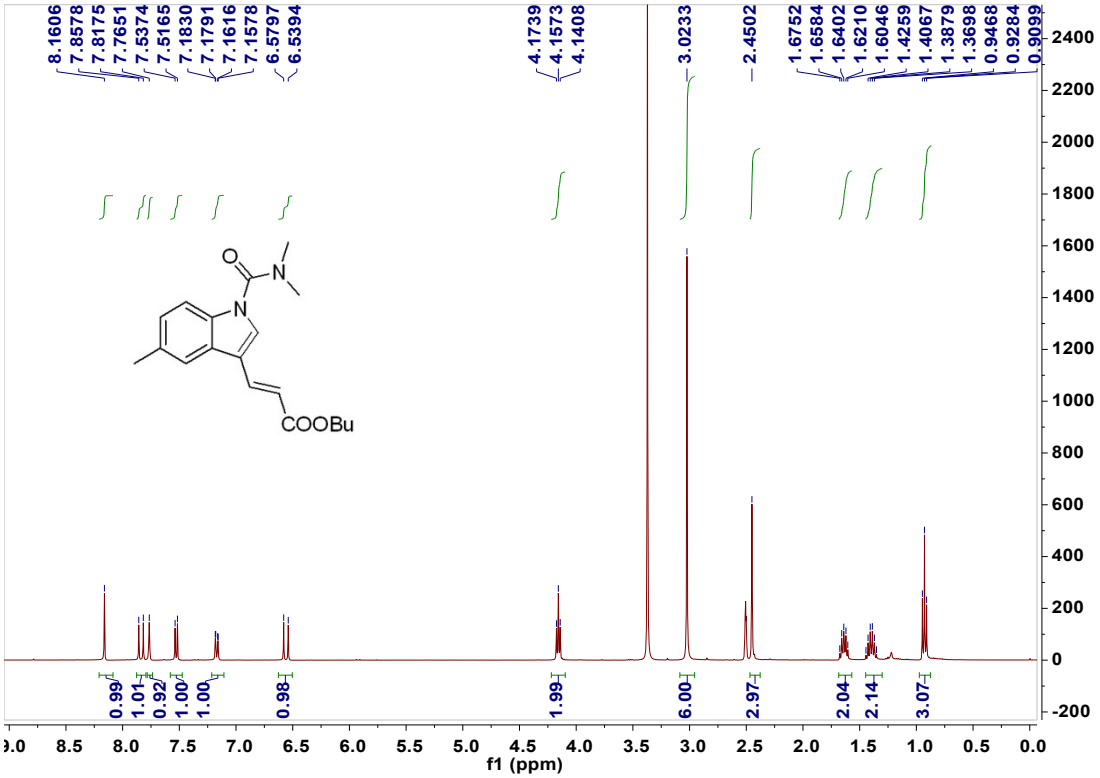
^{1}H NMR Spectrum (400 MHz, DMSO-d_6) of **5b**



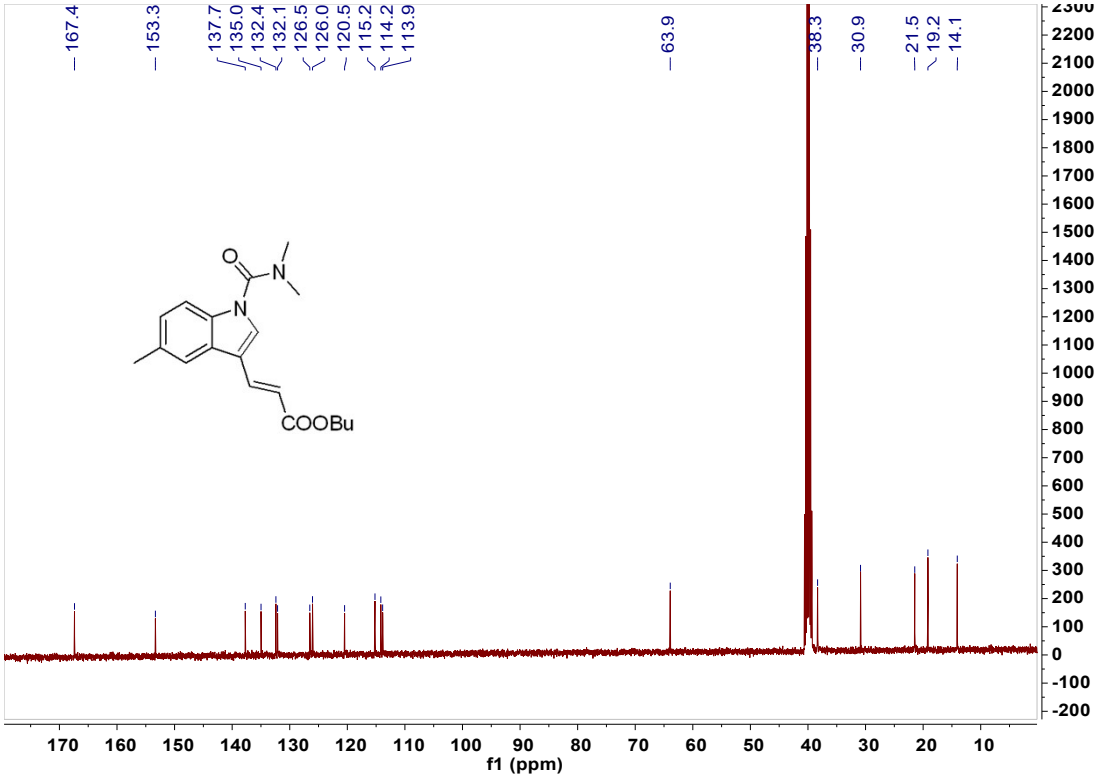
^{13}C NMR Spectrum (101 MHz, DMSO-d_6) of **5b**



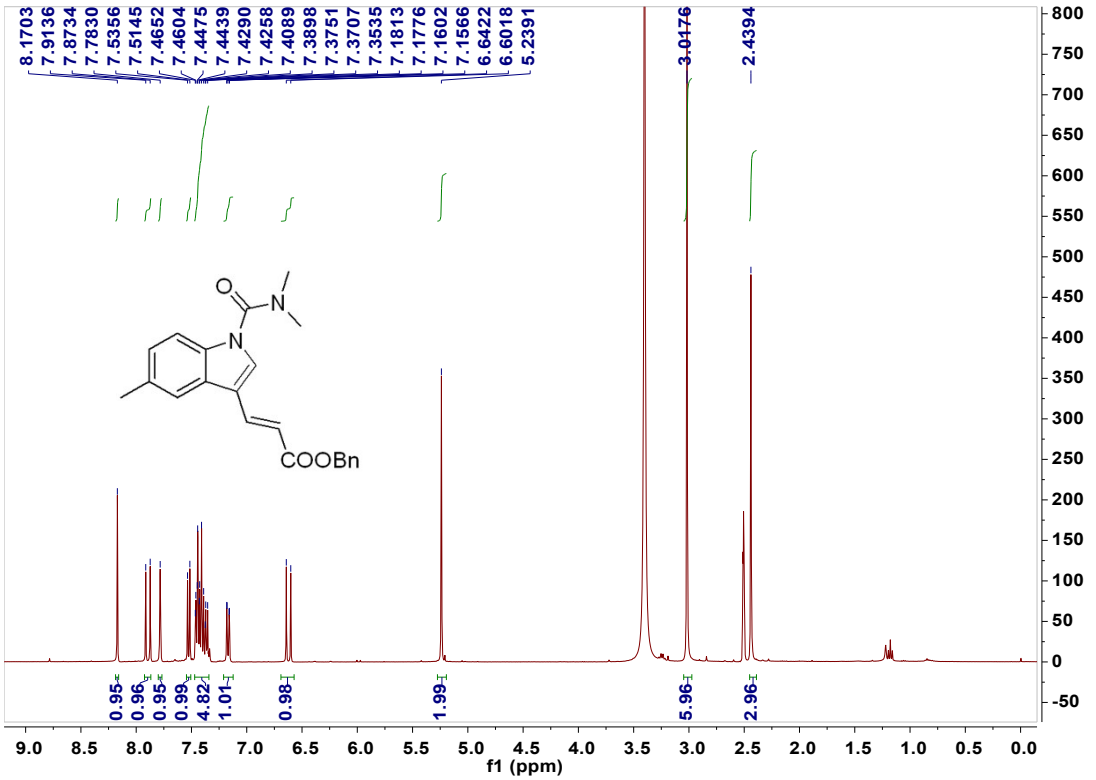
^{1}H NMR Spectrum (400 MHz, DMSO-d_6) of **5c**



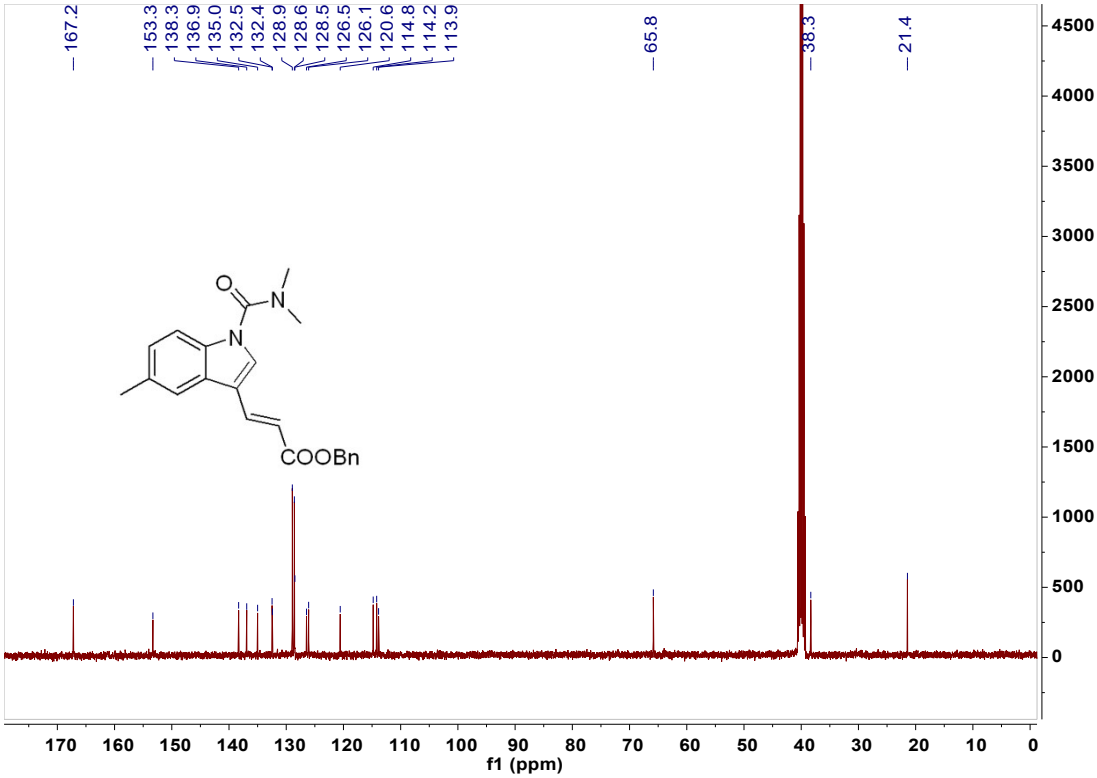
^{13}C NMR Spectrum (101 MHz, DMSO-d_6) of **5c**



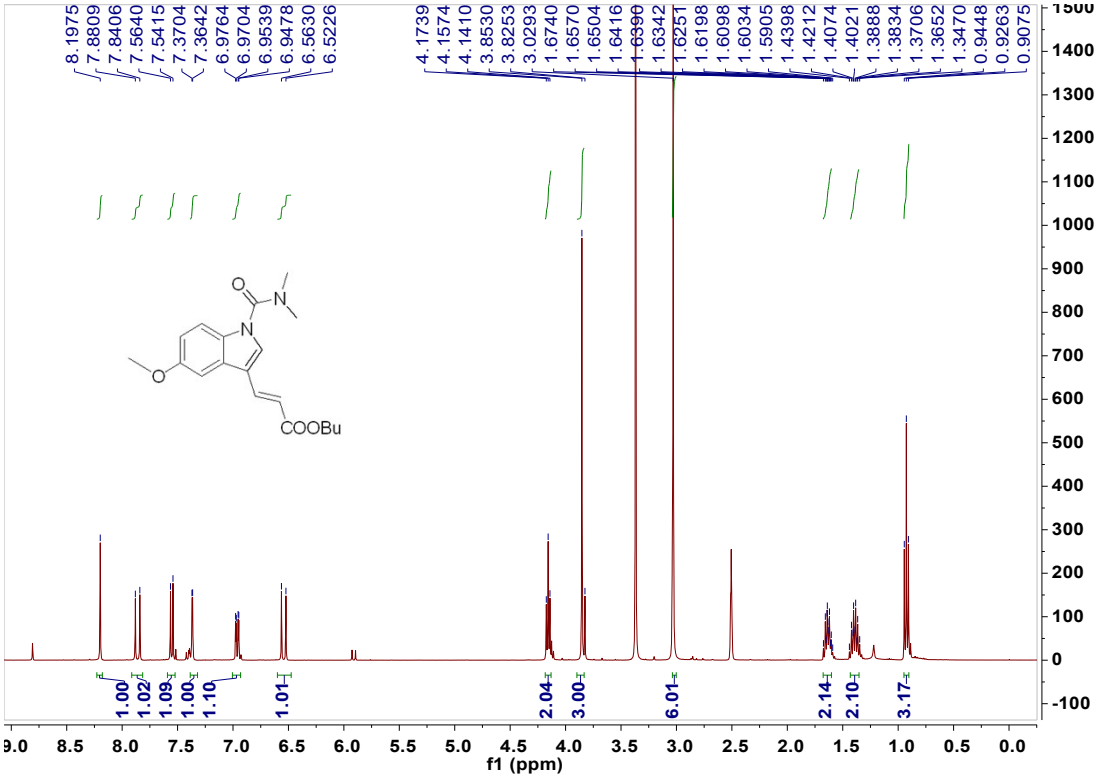
^{1}H NMR Spectrum (400 MHz, DMSO-d_6) of **5d**



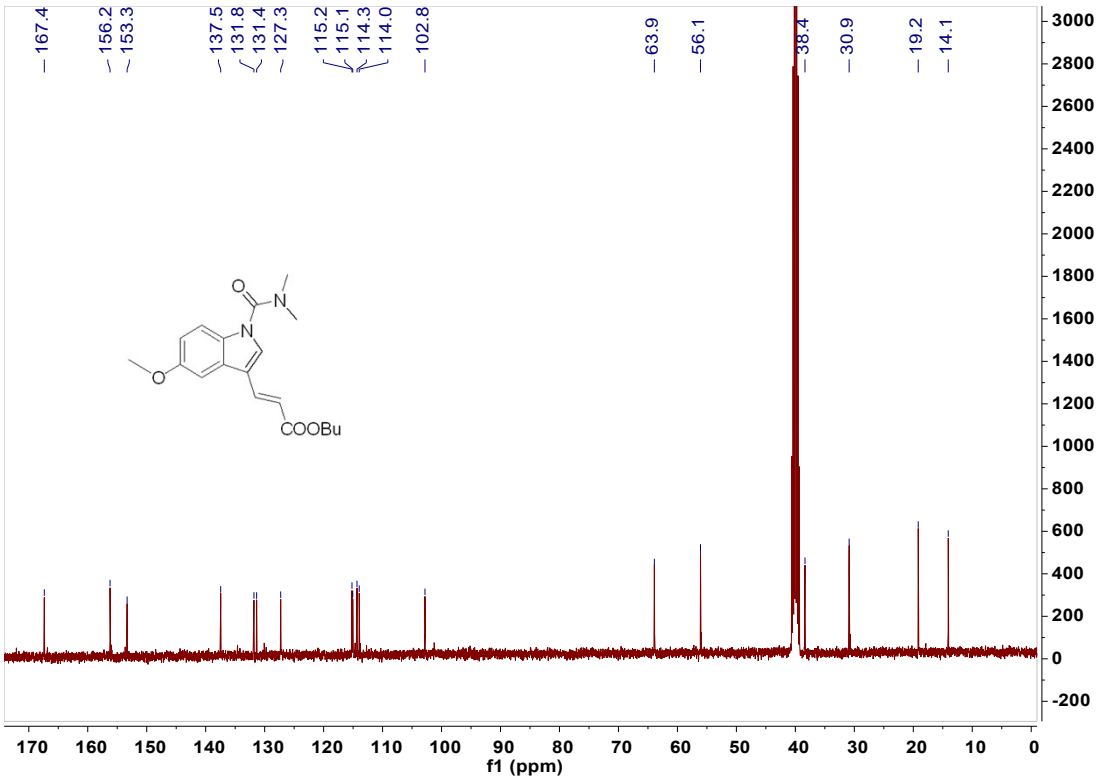
^{13}C NMR Spectrum (101 MHz, DMSO-d_6) of **5d**



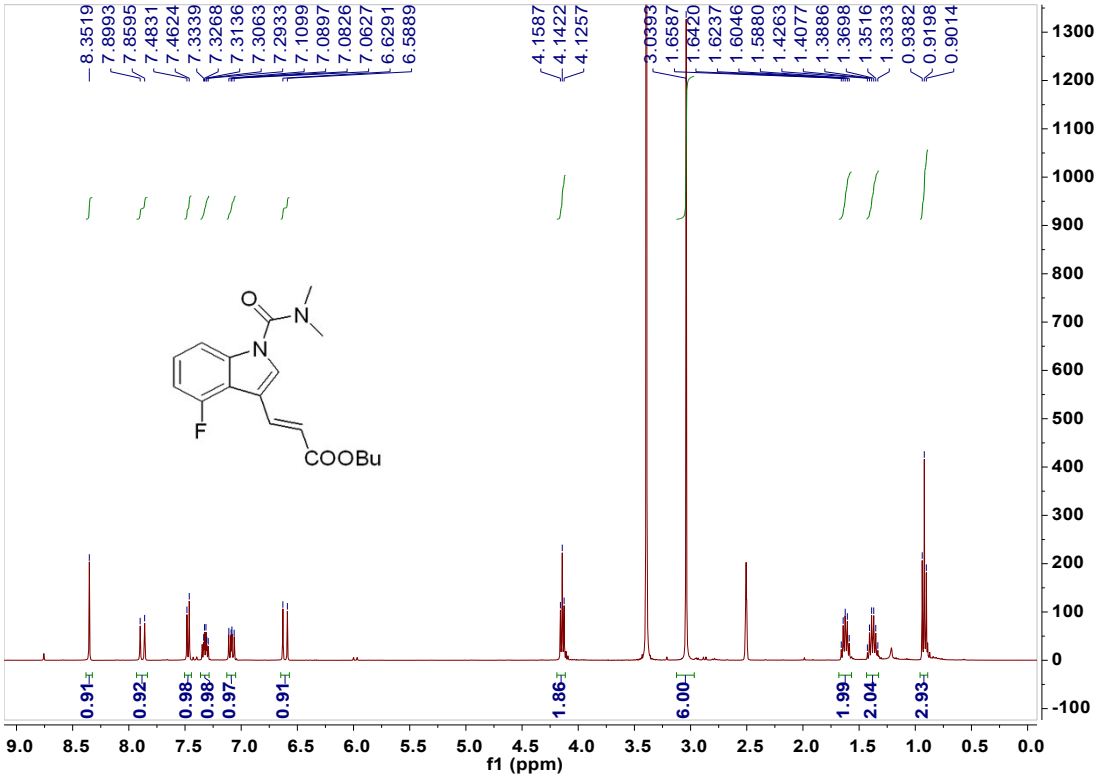
^{1}H NMR Spectrum (400 MHz, DMSO-d_6) of **5e**



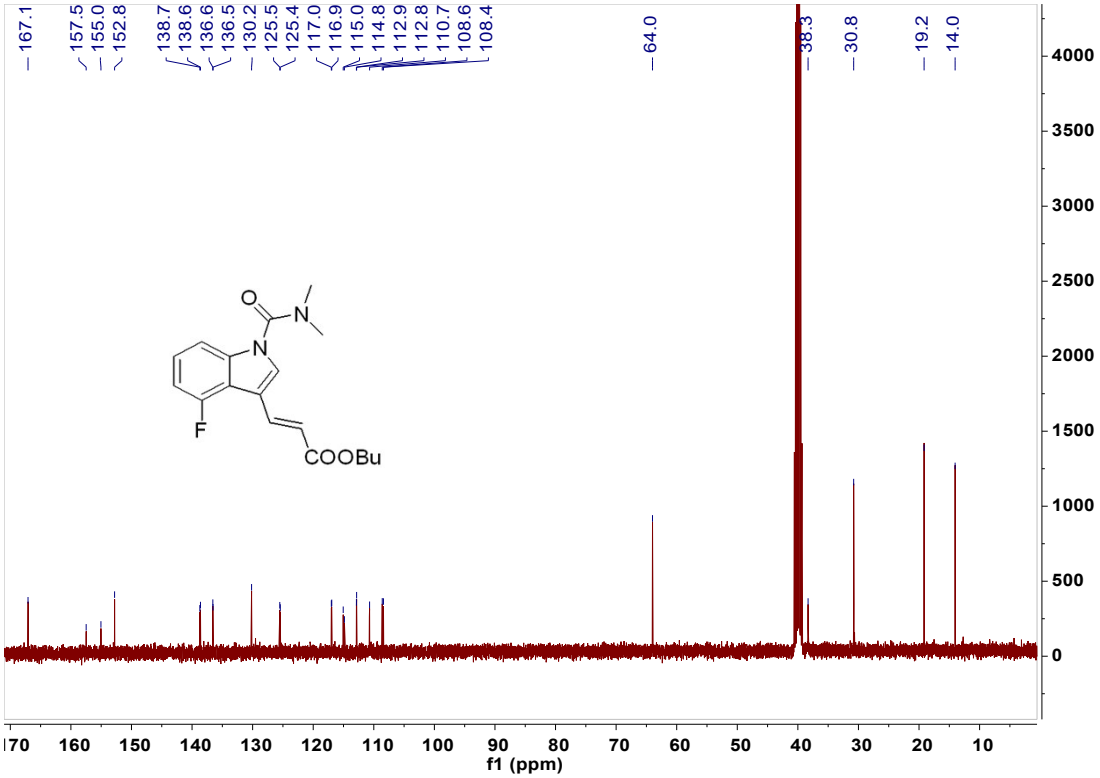
^{13}C NMR Spectrum (101 MHz, DMSO-d_6) of **5e**



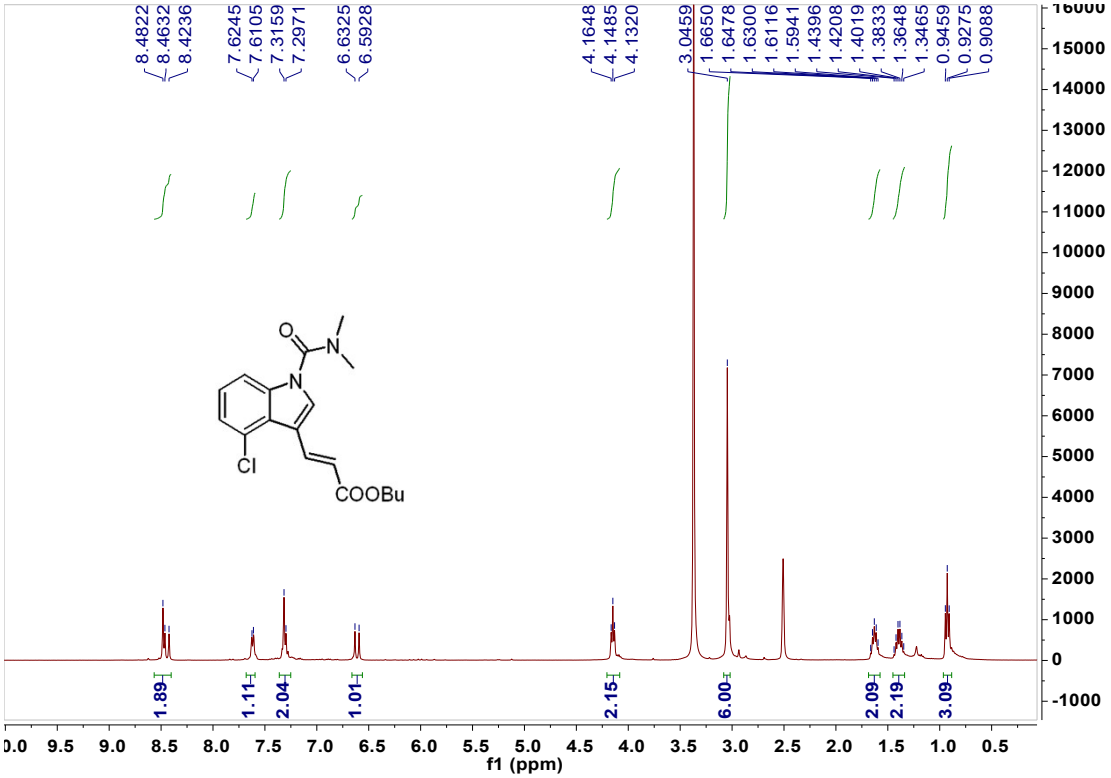
^{1}H NMR Spectrum (400 MHz, DMSO-d_6) of **5f**



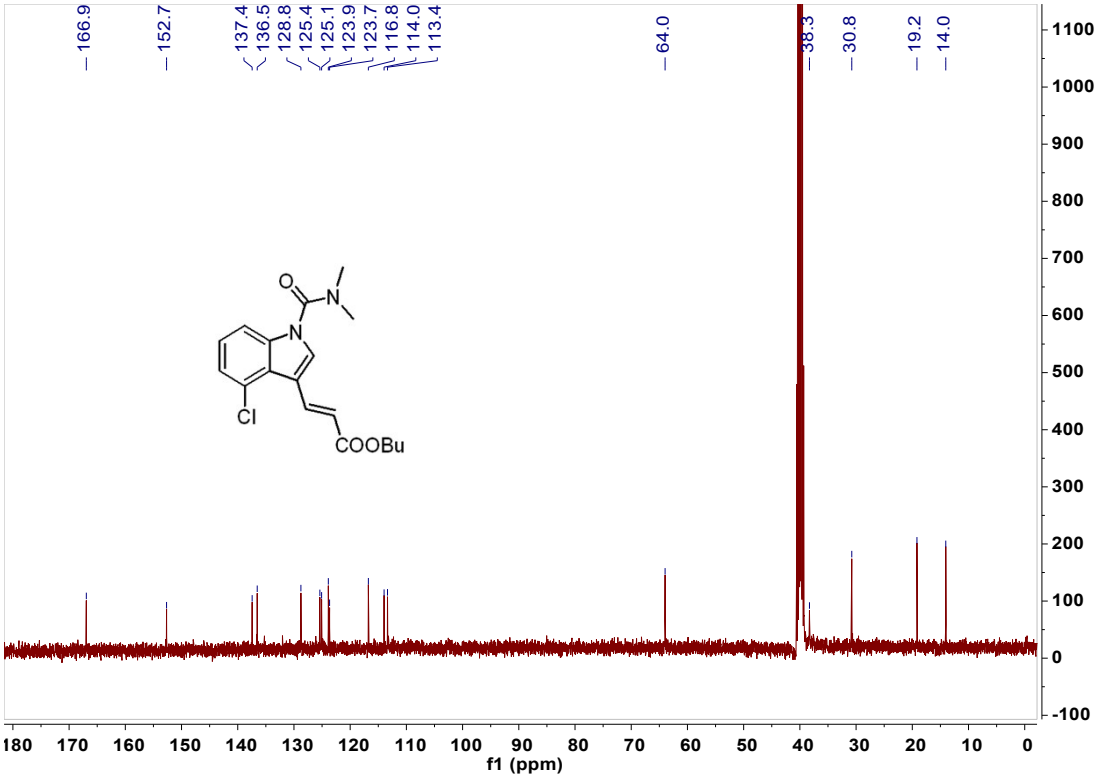
^{13}C NMR Spectrum (101 MHz, DMSO-d_6) of **5f**



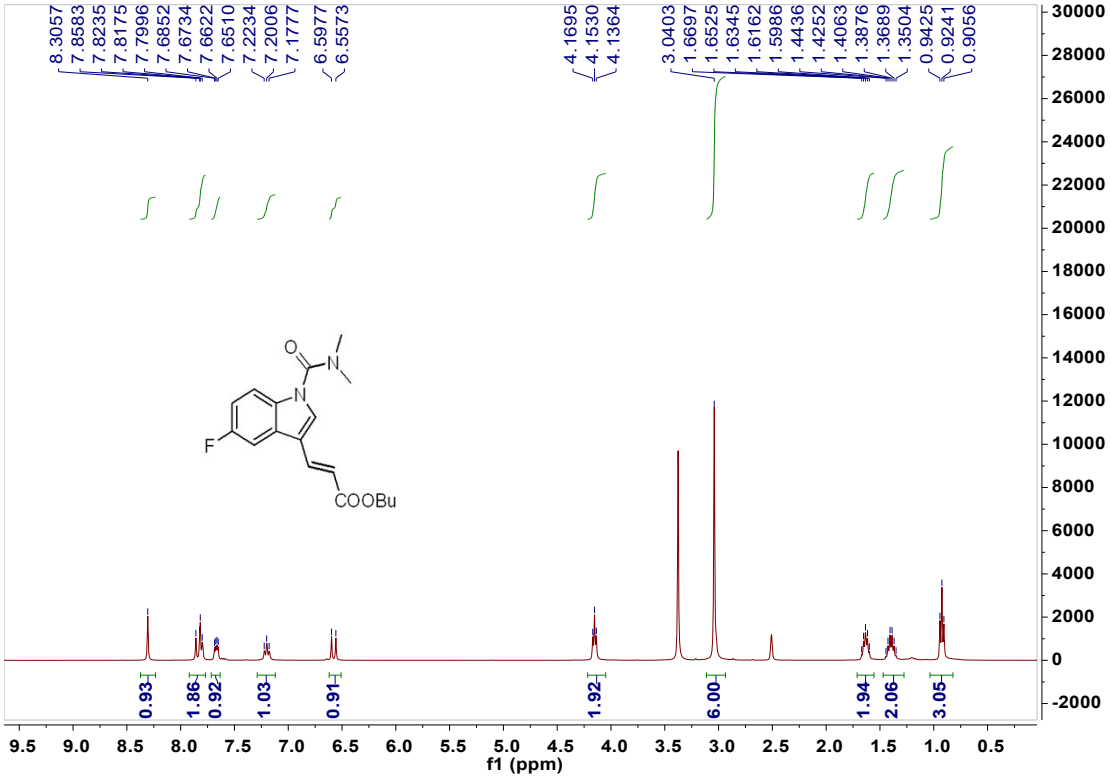
^{1}H NMR Spectrum (400 MHz, DMSO-d_6) of **5g**



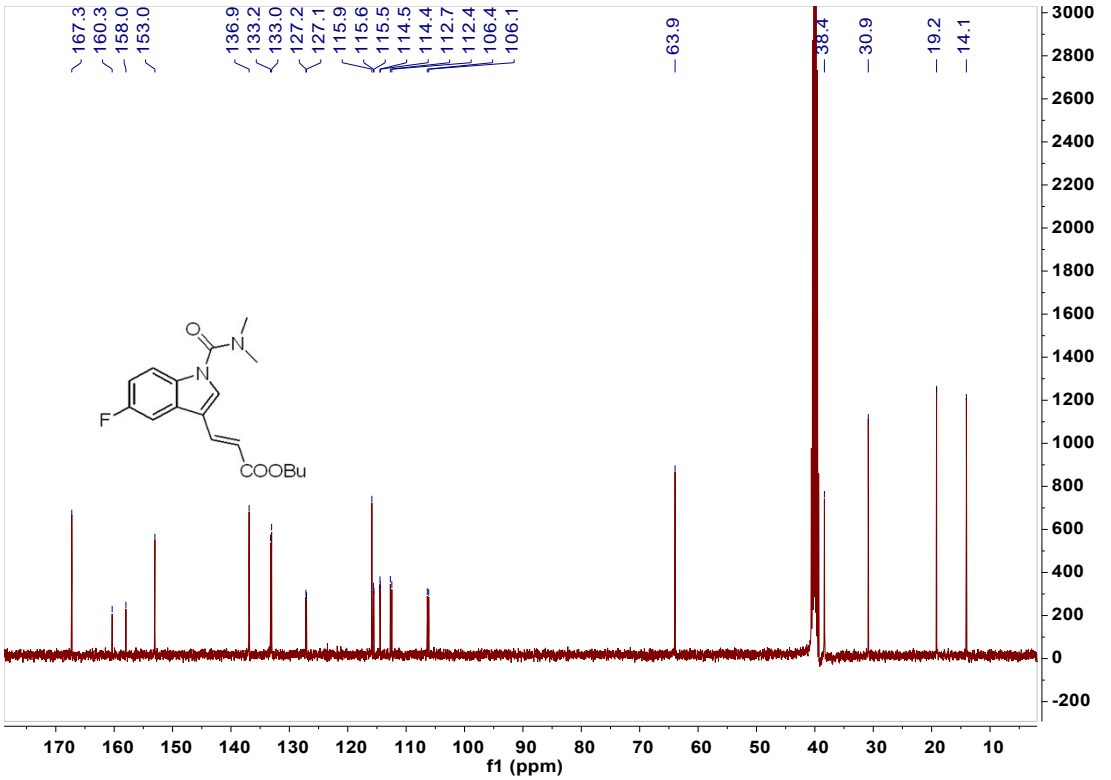
^{13}C NMR Spectrum (101 MHz, DMSO-d_6) of **5g**



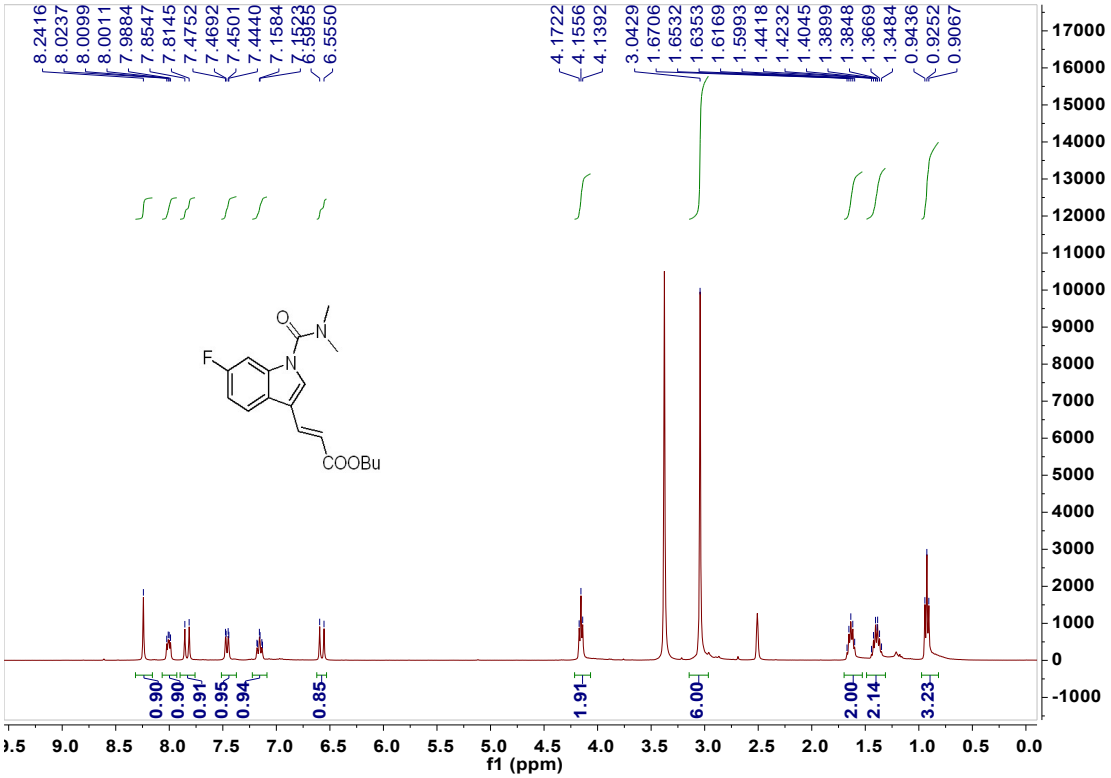
^{1}H NMR Spectrum (400 MHz, DMSO-d_6) of **5h**



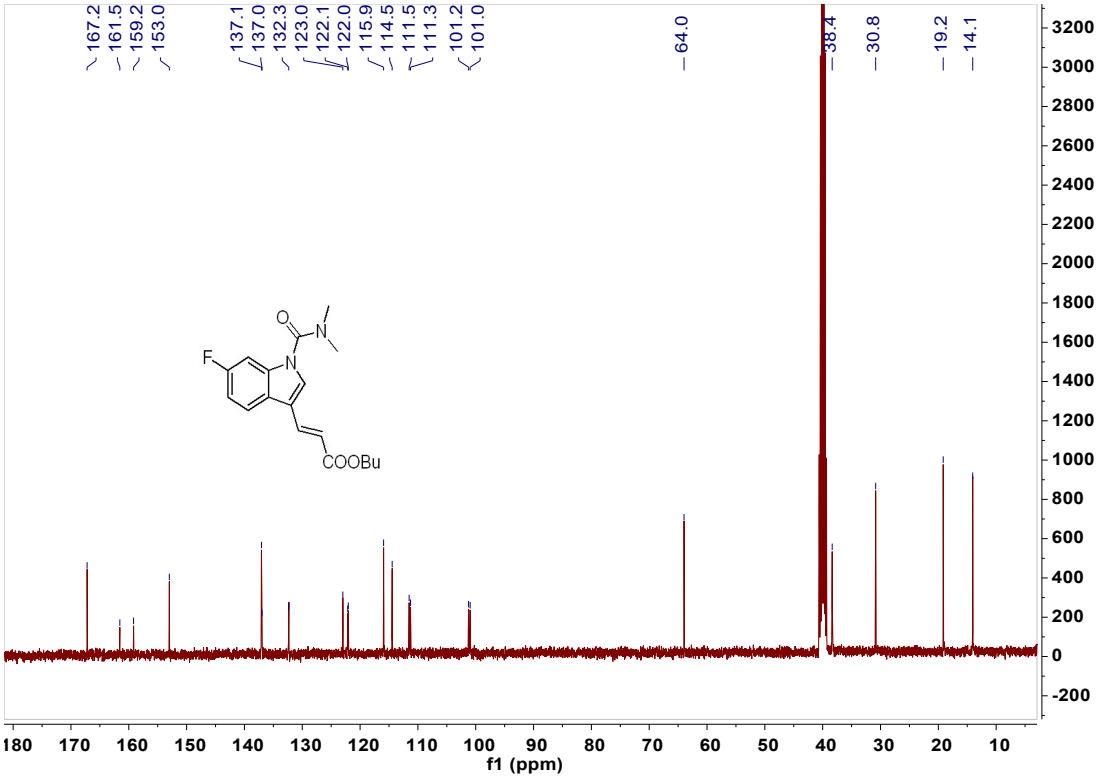
^{13}C NMR Spectrum (101 MHz, DMSO-d_6) of **5h**



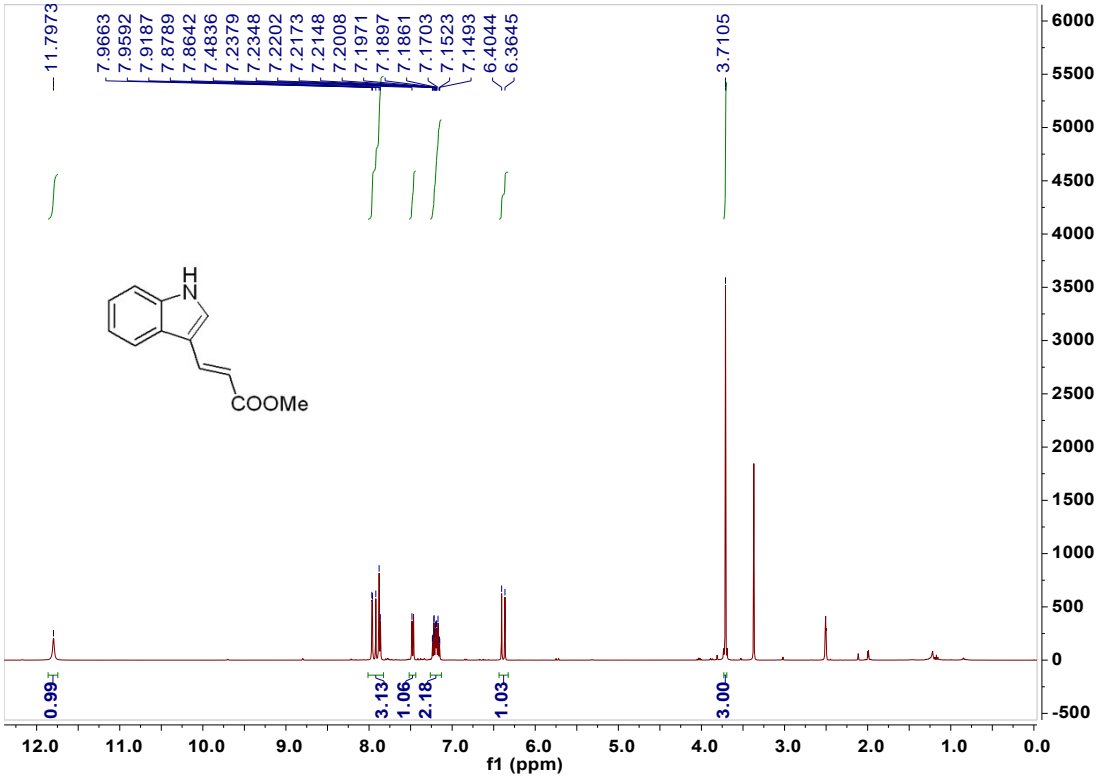
^{1}H NMR Spectrum (400 MHz, DMSO-d_6) of **5i**



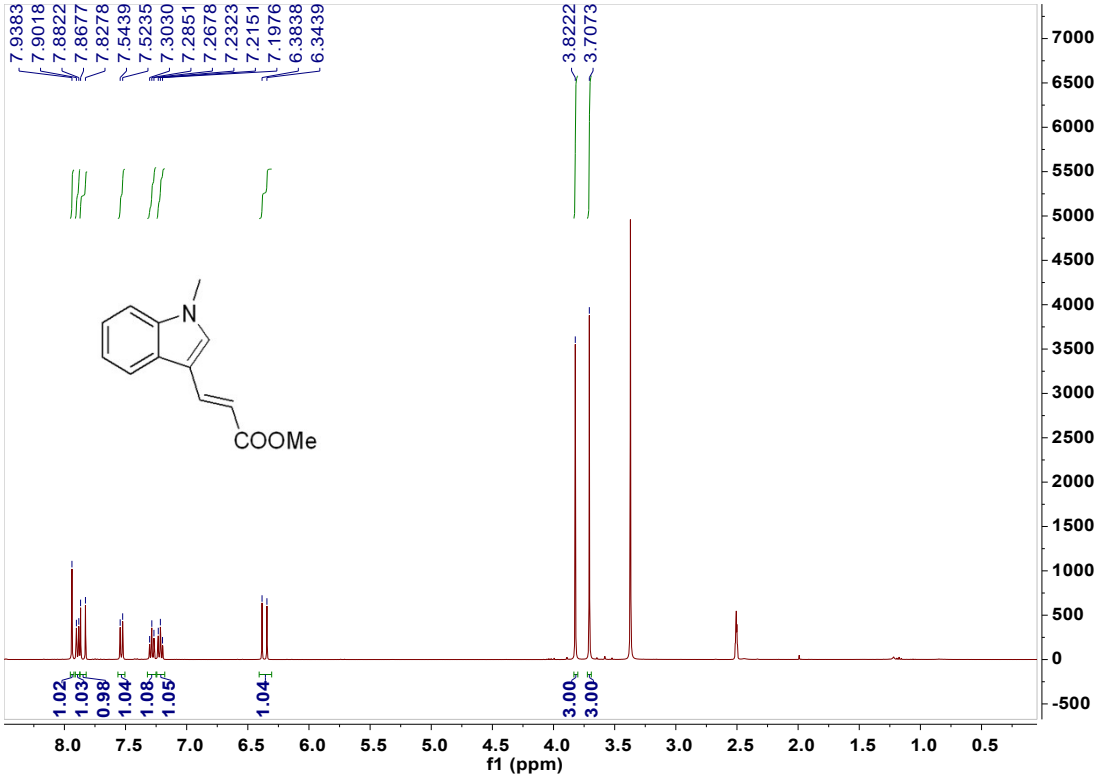
^{13}C NMR Spectrum (101 MHz, DMSO-d_6) of **5i**



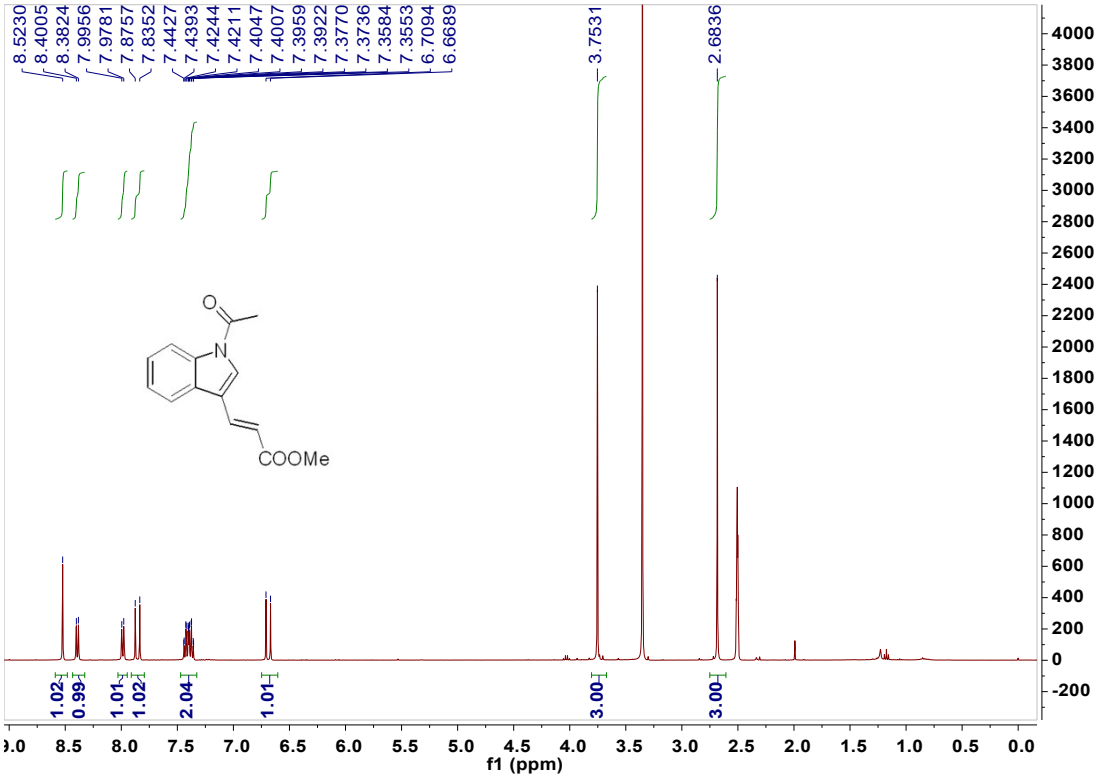
^{1}H NMR Spectrum (400 MHz, DMSO-d_6) of **6b**



^{1}H NMR Spectrum (400 MHz, DMSO-d_6) of **7b**



^{1}H NMR Spectrum (400 MHz, DMSO-d_6) of **8b**



^{1}H NMR Spectrum (400 MHz, DMSO-d_6) of **9**